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PROJECTION OPTICAL APPARATUS

[Claims]

[Claim 1] A projection optical apparatus which is characterized by the fact that in a projection optical apparatus [a] which has [i] a pulsed light source which emits exposing light as pulsed light, [ii] an illumination optical system which illuminates a mask on which a transfer pattern is formed with the above-mentioned exposing light at a uniform illuminance, [iii] a visual field diaphragm which sets the illumination area illuminated by the above-mentioned exposing light on the above-mentioned mask, [iv] a projection optical system which projects an image of the transfer pattern on the above-mentioned mask onto a photosensitive substrate, and [v] a relative scanning means which causes synchronized relative scanning of the above-mentioned mask and the above-mentioned photosensitive substrate in a specified direction of the illumination area illuminated by the above-mentioned exposing light, and [b] in which a transfer pattern image which has a broader area than that of the illumination area illuminated by the above-mentioned exposing light on the above-mentioned mask is exposed on the above-mentioned photosensitive substrate,

[1] [the apparatus is also] equipped with:

[i] a substrate moving means which causes the above-mentioned photosensitive substrate to undergo relative movement in a second direction that is perpendicular to the above-mentioned specified direction of the illumination area illuminated by the above-mentioned exposing light, and

[ii] an illuminance distribution setting means which causes the illuminance distribution in the above-mentioned second direction of the illumination area illuminated by the above-mentioned exposing light to have a trapezoidal shape, and

[2] the above-mentioned photosensitive substrate is relatively scanned a plurality of times in the above-mentioned specified direction of the illumination area illuminated by the above-mentioned exposing light while the above-mentioned photosensitive substrate is shifted in the above-mentioned second direction of the illumination area illuminated by the above-mentioned exposing light, so that an image of the transfer pattern of the above-mentioned mask or of a mask substituted for the above-mentioned mask is exposed on the above-mentioned photosensitive substrate.

[Claim 2] The projection optical apparatus claimed in Claim 1, which is characterized by the fact that the apparatus is [also] equipped with a memory means which stores the error in the relative positions of the above-mentioned mask and the above-mentioned photosensitive substrate when the above-mentioned mask and the above-mentioned photosensitive substrate are relatively scanned in synchronization in the above-mentioned specified direction of the illumination area illuminated by the above-mentioned exposing light.

[Claim 3] The projection optical apparatus claimed in Claim 1 or Claim 2, which is

characterized by the fact that the width LT of the transfer pattern formed on the above-mentioned mask is determined so that the equation

$$LT = n \bullet L + (n - 1) \bullet M$$

is satisfied using an integer n of 1 or greater, where L is the length of the area where the illuminance distribution is constant in the above-mentioned second direction of the illumination area with a trapezoidal illuminance distribution illuminated by the above-mentioned exposing light on the surface of the above-mentioned mask, M indicates the lengths of the areas where the illuminance gradually decreases on both sides of the above-mentioned area with a trapezoidal illuminance distribution, and LT is the width of the transfer pattern formed on the above-mentioned mask in the above-mentioned second direction of the illumination area illuminated by the above-mentioned exposing light.

[Claim 4] The projection optical apparatus claimed in Claim 1, 2 or 3, which is characterized by the fact that the apparatus is equipped with a mask moving means that causes relative movement of the above-mentioned mask in the above-mentioned second direction of the illumination area illuminated by the above-mentioned exposing light.

[Claim 5] A projection optical apparatus which is characterized by the fact that in a projection optical apparatus [a] which has [i] a pulsed light source which emits exposing light as pulsed light, [ii] an illumination optical system which illuminates a mask on which a transfer pattern is formed with the above-mentioned exposing light at a uniform illuminance, [iii] a visual field diaphragm which sets the illumination area illuminated by the above-mentioned exposing light on the above-mentioned mask, [iv] a projection optical system which projects an image of the transfer pattern on the above-mentioned mask onto a photosensitive substrate, and [v] a relative scanning means which causes synchronized relative scanning of the above-mentioned mask and the above-mentioned photosensitive substrate in a specified direction of the illumination area illuminated by the above-mentioned exposing light, and [b] in which a transfer pattern image which has a broader area than that of the illumination area illuminated by the above-mentioned exposing light on the above-mentioned mask is exposed on the above-mentioned photosensitive substrate,

[1] [the apparatus is also] equipped with:

[i] a substrate moving means which causes the above-mentioned photosensitive substrate to undergo relative movement in a second direction that is perpendicular to the above-mentioned specified direction of the illumination area illuminated by the above-mentioned exposing light,

[ii] a light emission position memory means which detects and stores the position of the above-mentioned photosensitive substrate in a direction conjugate with the above-mentioned specified direction when pulsed light is emitted by the above-mentioned pulsed light source, and

[iii] a light emission control means which controls the time of initiation of pulsed light emission by the above-mentioned pulsed light source, and

[2] the system is arranged so that when the above-mentioned mask or a mask substituted for the above-mentioned mask and the above-mentioned photosensitive substrate are relatively scanned a plurality of times in the above-mentioned specified direction of the illumination area

illuminated by the above-mentioned exposing light while the above-mentioned photosensitive substrate is shifted in the above-mentioned second direction of the illumination area illuminated by the above-mentioned exposing light, so that an image of the transfer pattern of the above-mentioned mask or mask substituted for the above-mentioned mask is exposed on the above-mentioned photosensitive substrate, the position of the above-mentioned photosensitive substrate in the direction conjugate with the above-mentioned specified direction when pulsed light is emitted by the above-mentioned pulsed light source in each of the above-mentioned relative scans is the same.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Utilization]

The present invention concerns a projection optical apparatus which is used to manufacture (for example) semiconductor integrated circuits or liquid crystal display elements, etc., using a lithographic process. More specifically, the present invention concerns a projection optical apparatus which is suitable for use as a projection exposure apparatus in which exposure is performed by means of a so-called stitching and slit scanning exposure system using a light source that emits pulsed light.

[0002]

[Prior Art]

When semiconductor elements or liquid crystal display elements, etc., are manufactured by a lithographic process, a projection exposure apparatus is employed which projects the pattern image of a photo-mask or reticle (hereafter referred to collectively as a "reticle") onto a photosensitive substrate via a projection optical system by means of exposing light. Such apparatuses include a projection exposure apparatus using a stitching and slit scanning exposure system as disclosed (for example) in Japanese Patent Application Kokoku No. SHO 46-34057. In the case of such a stitching and slit scanning exposure system, the exposure of a first linear area on the photosensitive substrate is accomplished by causing the relative synchronized scanning of the reticle and photosensitive substrate in a specified first direction with respect to an illumination area having a specified shape on the reticle.

[0003]

Afterward, the reticle is replaced, or else the reticle is moved by a specified amount in a second direction perpendicular to the first direction of the illumination area, so that the photosensitive substrate is laterally shifted (stitched) in a direction conjugate with the second direction of the illumination area. Then, the exposure of a second linear area on the photosensitive substrate is accomplished by again causing the relative synchronized scanning of

the reticle and photosensitive substrate in the [above-mentioned] first direction with respect to the illumination area having a specified shape on the reticle. In this way, the pattern of the reticle can be exposed in an area on the photosensitive substrate that is broader than the exposure field of the projection optical system.

[0004]

Figure 10 (a) shows the illumination area on the reticle in a conventional projection exposure apparatus using a stitching and slit scanning exposure system. In this Figure 10 (a), a regular hexagonal illumination area 1 centered on position A is illuminated with exposing light from the illumination optical system. Furthermore, the reticle is scanned at a constant speed V in the –X direction with respect to the illumination area 1 of the position A, so that the illumination area 1 moves in relative terms along the trace 2A over the reticle, and reaches a position B. In this state, the reticle is moved in the Y direction, so that the illumination area 1 moves in relative terms along the trace 2B over the reticle, and reaches a position C. Afterward, the reticle is scanned at a constant speed V in the X direction, so that the illumination area 1 moves in relative terms along the trace 2C over the reticle.

[0005]

Figure 10 (b) shows the area that is to be exposed on a wafer (used as a photosensitive substrate) in a conventional projection exposure apparatus using a stitching and slit scanning exposure system. In this Figure 10 (b), a regular hexagonal exposure area 3 centered on a position AP is an area that is conjugate with the illumination area 1 of the position A on the reticle. Two sides of the regular hexagonal exposure area 3 are parallel to the Y direction, and $W = 3^{1/2}R/2$ where R is the distance between two opposite vertices of the regular hexagonal exposure area 3, and W is the distance between two opposite sides of this area. Furthermore, as a result of the wafer being scanned in the X direction with respect to the exposure area 3 of the position AP at a constant speed of $\beta \bullet V$ (where β is the projection magnification of the projection optical system from the reticle to the wafer), the exposure area 3 moves in relative terms along the trace 2AP over the wafer, and reaches a position BP. In this state, the wafer moves by a distance of 3R/4 in the –Y direction, so that the exposure area 3 moves in relative terms along the trace 2BP over the wafer, and reaches a position CP. This operation is stitching. Afterward, as a result of the wafer being scanned at a constant speed of $\beta \bullet V$ in the –X direction, the exposure area 3 moves in relative terms along the trace 2CP over the wafer.

[0006]

Furthermore, the exposure area 3 moving in relative terms along the trace 2AP and the exposure area 3 moving in relative terms along the trace 2CP are scanned so that respective areas of two equal sides and three angles with a width of R/4 in the Y direction are caused to overlap in a connecting area 4. Accordingly, exposure is performed twice in this connecting area 4. This connecting area 4 is provided in order to insure that no positional deviation occurs between the pattern exposed by the exposure area 3 that moves in relative terms along the trace 2AP and the

pattern exposed by the exposure area 3 that moves in relative terms along the trace 2CP. Furthermore, as will be shown next, the illuminance distribution on the wafer is made uniform by arranging the system so that the [above-mentioned] areas with two equal sides and three angles [forming parts] of the regular hexagonal exposure area 3 overlap.

[0007]

Conventionally, a light source with continuous emission such as a mercury lamp has generally been used as a source of exposing light. Accordingly, the exposure point P1 in the connecting area 4 on the wafer is continuously exposed by the area 5A of the exposure area 3 that moves relatively along the trace 2AP, and is continuously exposed by the area 6A of the exposure area 3 that moves relatively along the trace 2CP. The total of the lengths of the area 5A and area 6A in the X direction is equal to the width W of the exposure area 3. Furthermore, a different exposure point P2 in the connecting area 4 on the wafer is continuously exposed by the area 5B of the exposure area 3 that moves relatively along the trace 2AP, and is continuously exposed by the area 6B of the exposure area 3 that moves relatively along the trace 2CP. The total of the lengths of the area 5B and area 6B in the X direction is equal to W. Furthermore, the exposure point P0 in the non-connecting area that is exposed only by the exposure area 3 that moves relatively along the trace 2AP is continuously exposed by an area with a width of W in the X direction. Accordingly, in cases where a continuous emission type light source is used, all of the exposure points P0, P1 and P2 on the wafer are illuminated by the same amount of exposing light, so that the illuminance distribution is uniform.

[0008]

[Problems to Be Solved by the Invention]

Recently, there has been a demand for shortened wavelengths of exposing light in order to achieve a further increase in resolution. Light sources with relatively short wavelengths among those light sources currently at the level of practical use include metal vapor lasers and excimer lasers such as ArF excimer lasers (wavelength: 193 nm) and KrF excimer lasers (wavelength: 248 nm), etc. However, excimer laser light sources and metal vapor laser light sources are pulsed emission (pulse oscillation) type light sources; accordingly, the use of such light sources involves considerations that differ from those involved in continuous emission light sources such as mercury lamps.

[0009]

Figure 11 (a) illustrates a case in which a regular hexagonal exposure area 3 is illuminated by pulsed laser light from a pulsed laser light source. In this Figure 11 (a), the exposure area 3 is an area that is in inside contact with the outline of the circular exposure area 7 of the projection optical system on the wafer. Furthermore, two opposite sides of the exposure area 3 with a spacing of W are parallel to the Y direction, and the wafer is relatively scanned in the X direction and –X direction with respect to the exposure area 3. In this case, it is necessary that each

exposure point on the wafer be exposed by a plurality of pulses of the pulsed laser light in order to lessen the effects of the spectrum and variation in the energy per pulse, etc., of the pulsed laser light. Accordingly, the exposure point P0 which is exposed by an area with a width of W in the X direction of the exposure area 3 is exposed m times (m is an integer greater than 1) by the pulsed laser light. Here, it is sufficient if the following relationship holds true where ΔL is the distance that the wafer is scanned in the X direction or –X direction during one period T of the pulsed light emission, and $\beta \bullet V$ is the scanning speed of the wafer.

[Numerical Expression 1]

$$W = m \bullet \Delta L - m \bullet T \bullet \beta \bullet V$$

[0010]

Figure 11 (a) shows a case where m = 8. Assuming that the exposure point P0 is at the edge of the exposure area 3 at the point in time where pulsed light emission occurs, this exposure point P0 will be exposed seven times by the pulsed laser light in the interior portion of the exposure area 3, and will be exposed twice by the pulsed laser light in the edge areas. In this case, since the energy of exposure in the edge areas is 1/2 the energy of exposure in the interior portion [of the exposure area 3], the exposure point P0 is illuminated by a total energy equal to 8 pulses. Furthermore, the exposure point P0 is illuminated by a total energy equal to 8 pulses regardless of the position of the exposure point P0 in the X direction at the time of pulsed light emission. Moreover, among the exposure points through which the area 3a with two equal sides and three angles located on the right side of the exposure area 3 passes, the distances for which the exposure points P1 through P8 shown in Figure 11 (a) pass through this area 3a with two equal sides and three angles are $8 \bullet \Delta L$ to $1 \bullet \Delta L$, respectively. Accordingly, these exposure points P1 through P8 are illuminated by respective amounts of energy ranging from 8 pulses to 1 pulse when the exposure points pass through the area 3a in the X direction.

[0011]

Next, when the wafer is scanned in the –X direction with respect to the exposure area 3 after stitching of the wafer has been performed, the exposure points P1 through P8 are respectively exposed by an energy ranging from more or less 0 pulses to 7 pulses. Accordingly, as a result of slit scanning exposure being performed twice by means of stitching, all of the exposure points P1 through P8 are respectively exposed by an energy equal to 8 pulses, in the same manner as the exposure point P0.

However, if an exposure point that is intermediate between the exposure point P4 and the exposure point P5 in Figure 11 (a) is designated as exposure point P9 in Figures 11 (b) and 11 (c), the following inconvenience is encountered in the case of this exposure point P9: namely, the illumination energy varies even if slit scanning exposure is performed twice. Specifically, in the case illustrated in Figure 11 (b), when the wafer is scanned in the X direction within the area 3a having two equal sides and three angles on the right side of the exposure area 3, pulsed light

emission is performed when the exposure point P9 is at a position 8; then, when the wafer is scanned in the X direction within the area 3b having two equal sides and three angles on the left side of the exposure area 3 following stitching, pulsed light emission is performed when the exposure point P9 is at a position 9. Accordingly, the exposure point P9 is illuminated by energy equal to nine pulses.

[0012]

Meanwhile, in the case illustrated in Figure 11 (c), when the wafer is scanned in the X direction within the area 3a having two equal sides and three angles on the right side of the exposure area 3, pulsed light emission is performed when the exposure point P9 is at a position 10, and when the wafer is scanned in the X direction within the area 3b having two equal sides and three angles on the left side of the exposure area 3 following stitching, pulsed light emission is performed when the exposure point P9 is at a position 11. Accordingly, the exposure point P9 is illuminated by energy equal to seven pulses. Thus, depending on the timing of the pulsed light emission, the exposure point P9 is illuminated by energy equal to seven to nine pulses. Accordingly, the problem of irregular illumination energy generated by the pulsed laser light, i. e., irregular illuminance, arises in the connecting area 4 on the wafer.

[0013]

In light of such points, the object of the present invention is to reduce illuminance irregularity in the connecting area exposed by being scanned twice by stitching on the photosensitive substrate in cases where the light source is a pulsed emission type light source in a projection optical apparatus in which exposure is performed using a stitching and slit scanning exposure system.

[0014]

[Means Used to Solve the Problems]

The first projection optical apparatus of the present invention presupposes a projection optical apparatus [a] which has [i] a pulsed light source (34) which emits exposing light as pulsed light, [ii] an illumination optical system (13, 16, 18) which illuminates a mask (19) on which a transfer pattern is formed with the above-mentioned exposing light at a uniform illuminance, [iii] a visual field diaphragm (15) which sets the illumination area (20) illuminated by the above-mentioned exposing light on the mask (19), [iv] a projection optical system (27) which projects an image of the transfer pattern on the mask (19) onto a photosensitive substrate (28), and [v] a relative scanning means (25, 26, 33) which causes synchronized relative scanning of the mask (19) and the photosensitive substrate (28) in a specified direction of the illumination area (20) illuminated by the above-mentioned exposing light, and [b] in which a transfer pattern image which has a broader area than that of the illumination area (20) illuminated by the above-mentioned exposing light on the mask (19) is exposed on the photosensitive substrate (28), as is shown for example in Figures 1 and 2.

[0015]

Furthermore, in the present invention, [1] [the apparatus is also] equipped with [i] a substrate moving means (30, 33) which causes the photosensitive substrate (28) to undergo relative movement in a second direction (Y direction) that is perpendicular to the above-mentioned specified direction (X direction) of the illumination area (20) illuminated by the above-mentioned exposing light, and [ii] an illuminance distribution setting means (13, 15) which causes the illuminance distribution in the above-mentioned second direction of the illumination area (20) illuminated by the above-mentioned exposing light to have a trapezoidal shape (for example, as shown in Figure 2 (b)), and [2] the photosensitive substrate (28) is relatively scanned a plurality of times in the above-mentioned specified direction of the illumination area (20) illuminated by the above-mentioned exposing light while the photosensitive substrate (28) is shifted in the above-mentioned second direction of the illumination area (20) illuminated by the above-mentioned exposing light, so that an image of the transfer pattern of the mask (19) or of a mask substituted for the above-mentioned mask is exposed on the photosensitive substrate (28).

[0016]

In this case, it is desirable that [the apparatus be] equipped with a memory means (25a) which stores the error in the relative positions of the mask (19) and the photosensitive substrate (28) when the mask (19) and the photosensitive substrate (28) are relatively scanned in synchronization in the above-mentioned specified direction of the illumination area (20) illuminated by the above-mentioned exposing light.

Furthermore, it is desirable that the width LT [of the transfer pattern formed on the mask (19)] be determined so that the following equation is satisfied using an integer n of 1 or greater, where L is the length of the area where the illuminance distribution is constant in the above-mentioned second direction of the illumination area (20) with a trapezoidal illuminance distribution illuminated by the above-mentioned exposing light on the surface of the mask (19), M indicates the lengths of the areas where the illuminance gradually decreases on both sides of the above-mentioned area with a trapezoidal illuminance distribution, and LT is the width of the transfer pattern formed on the mask (19) in the above-mentioned second direction of the illumination area (20) illuminated by the above-mentioned exposing light.

[Numerical Expression 2]

$$LT = n \bullet L + (n - 1) \bullet M$$

[0017]

Furthermore, it is desirable that [the apparatus be] equipped with a mask moving means (21, 26) that causes relative movement of the mask (19) in the above-mentioned second direction of the illumination area (20) illuminated by the above-mentioned exposing light.

Next, the second projection optical apparatus of the present invention presupposes a projection optical apparatus [a] which has [i] a pulsed light source (12) which emits exposing light as pulsed light, [ii] an illumination optical system (13, 16, 18) which illuminates a mask (19) on which a transfer pattern is formed with the above-mentioned exposing light at a uniform illuminance, [iii] a visual field diaphragm (15) which sets the illumination area (20) illuminated by the above-mentioned exposing light on the mask (19), [iv] a projection optical system (27) which projects an image of the transfer pattern on the mask (19) onto a photosensitive substrate (28), and [v] a relative scanning means (25, 26, 33) which causes synchronized relative scanning of the mask (19) and the photosensitive substrate (28) in a specified direction of the illumination area (20) illuminated by the above-mentioned exposing light, and [b] in which a transfer pattern image which has a broader area than that of the illumination area (20) illuminated by the above-mentioned exposing light on the mask (19) is exposed on the photosensitive substrate (28), as is shown for example in Figure 1.

[0018]

Furthermore, in the present invention, [1] [the apparatus is also] equipped with [i] a substrate moving means (30, 33) which causes the photosensitive substrate (28) to undergo relative movement in a second direction (Y direction) that is perpendicular to the above-mentioned specified direction (X direction) of the illumination area (20) illuminated by the above-mentioned exposing light, [ii] a light emission position memory means (25, 25a) which detects and stores the position of the photosensitive substrate (28) in a direction conjugate with the above-mentioned specified direction when pulsed light is emitted by the pulsed light source (12), and [iii] a light emission control means (34) which controls the time of initiation of pulsed light emission by the pulsed light source (12), and [2] the system is arranged so that when the mask (19) or a mask substituted for the above-mentioned mask and the photosensitive substrate (28) are relatively scanned a plurality of times in the above-mentioned specified direction of the illumination area (20) illuminated by the above-mentioned exposing light while the photosensitive substrate (28) is shifted in the above-mentioned second direction of the illumination area (20) illuminated by the above-mentioned exposing light, so that an image of the transfer pattern of the mask (19) or mask substituted for the above-mentioned mask is exposed on the photosensitive substrate (28), the position of the photosensitive substrate (28) in the direction conjugate with the above-mentioned specified direction (X direction) when pulsed light is emitted by the pulsed light source (12) in each of the above-mentioned relative scans is the same, as shown for example in Figure 9.

[0019]

[Operation]

In the first projection optical apparatus of the present invention, the illuminance distribution of the illumination area (20) illuminated by the above-mentioned exposing light on the mask (19) in the above-mentioned second direction perpendicular to the above-mentioned specified direction of the illumination area (20), i. e., in the direction perpendicular to the

direction of relative scanning, has a trapezoidal shape. As a result, the illuminance distribution of the exposure area (20P) conjugate with the illumination area (20) on the surface of the photosensitive substrate (28) in the above-mentioned second direction (Y direction) also has a trapezoidal shape, as shown in Figure 5. In this case, if the width of the exposure area (20P) in the direction of relative scanning is constant, then the respective exposure points lined up in the second direction on the photosensitive substrate (28) that is relatively scanned by the exposure area (20P) will each be illuminated by the same number of pulses of exposing light.

[0020]

Furthermore, the system is arranged so that when the exposure area (20P) is laterally shifted on the photosensitive substrate (28) by stitching, the areas (20aP and 20bP) in which the illuminance distribution [*sic*] gradually drops overlap as shown in Figure 5. As a result, in the case of the exposure point Q3 located in the connecting area (40c) that is scanned twice because of stitching, the sum of the illuminance SA during the first scan and the illuminance SB during the second scan is equal to the illuminance SC in the area where the illuminance distribution [*sic*] is constant in the trapezoidal illuminance distribution. Accordingly, the illuminance at an arbitrary exposure point in the connecting area (40c) on the photosensitive substrate (28) is more or less equal to the illuminance at exposure points in the non-connecting areas, so that irregularity in the illuminance is reduced. In the connecting area (40c), furthermore, since the number of illuminating pulses of the pulsed exposing light is twice the number of pulses in the non-connecting areas, the effects of the spectrum and irregularity in the illuminance caused by variation between individual pulses are especially reduced.

[0021]

Next, in cases where a memory means (25a) is provided which stores the error in the relative positions of the mask (19) and photosensitive substrate (28) when the mask (19) and photosensitive substrate (28) are relatively scanned in synchronization in the above-mentioned specified direction of the illumination area (20) illuminated by the exposing light, the amounts of relative positional deviation of the mask (19) and photosensitive substrate (28) in the first slit scanning exposure (for example) are stored. Then, the amounts of positional deviation of the mask (19) and photosensitive substrate (28) at the time of the second slit scanning exposure following stitching can be combined with the stored amounts of positional deviation, so that the precision of overlapping in the connecting area can be improved.

[0022]

Furthermore, as shown for example in Figure 3, the length of the area in which the illuminance distribution is constant in the second direction of the illumination area (20) with a trapezoidal illuminance distribution caused by the exposing light on the mask (19) is designated as L, the lengths of the areas in which the illuminance gradually decreases on both sides of the area with a trapezoidal illuminance distribution are respectively designated as M, and the width of the transfer pattern (35) formed on the mask (19) in the above-mentioned second direction of the

illumination area (20) illuminated by the exposing light is designated as LT. In this case, assuming that the illumination area (20) is scanned n times on the mask (19) by stitching, so that the pattern (35) on the mask (19) is exposed on the photosensitive substrate (28), it is then necessary that the areas with a length of M in which the illuminance distribution gradually decreases overlap in the connecting area (35c) of the illumination area (20). However, in order to maintain the illuminance distribution in both end portions of the pattern (35) at the same level as the distribution in the central portion, it is desirable that the light in the areas with a length of M in which the illuminance distribution decreases be blocked in both end portions of the pattern (35). Accordingly, the width LT of the pattern (35) in the above-mentioned second direction is as shown in (Numerical Expression 2).

[0023]

Furthermore, in cases where a mask moving means (21, 26) is provided which causes the mask (19) to move in relative terms in the second direction of the illumination area (20) illuminated by the exposing light, stitching can also be performed with respect to the mask (19).

Next, in the second projection optical apparatus of the present invention, even in cases where (for example) the photosensitive substrate (28) is scanned by a regular hexagonal exposure area (3) as shown in Figure 9 (a), the position (8) of the pulsed emission of the exposing light during the first scan and the position (42) of the pulsed emission of the exposing light during the second scan with respect to an arbitrary exposure point P9 in the connecting area (4) are equal. In the case illustrated in Figure 9 (a), the exposure point P9 is illuminated by an amount of energy equal to eight pulses. Furthermore, in the case illustrated in Figure 9 (b), although the timing of the pulsed light emission is shifted from that in Figure 9 (a), the position (10) of the pulsed emission of the exposing light during the first scan and the position (43) of the pulsed emission of the exposing light during the second scan with respect to the exposure point P9 are equal. Furthermore, in the case of Figure 9 (b) as well, the exposure point P9 is illuminated by an amount of energy equal to eight pulses. In other words, in the connecting area (4) that is scanned twice as a result of stitching, the area is always illuminated by a constant energy as a result of the positions of pulsed light emission during the two scans being set so that the positions are the same; consequently, the irregularity in illuminance is decreased.

[0024]

[Working Examples]

Below, one working example of the projection optical apparatus of the present invention will be described with reference to Figures 1 through 7. In the present working example, the present invention is applied to a projection exposure apparatus using a stitching and slit scanning exposure system, which is equipped with a pulsed emission type laser light source.

Figure 1 shows the overall construction of the projection exposure apparatus of the present working example. In Figure 1, a laser beam LB emitted from a pulsed laser light source

12 such as an excimer laser light source, etc., enters an illumination-optimizing optical system 13 consisting of a beam expander, an optical integrator, an aperture diaphragm and a relay lens, etc. The pulsed laser light IL emitted from the illumination-optimizing optical system 13 as exposing light is reflected by a deflecting mirror 14, and enters a visual field diaphragm 15. The pulsed laser light IL passing through the aperture of the visual field diaphragm 15 passes through a relay lens 16, deflecting mirror 17 and condenser lens 18, and illuminates a reticle 19 with a uniform luminance. The plane in which the visual field diaphragm 15 is installed is conjugate with the pattern formation surface of the reticle 19, so that the shape of the slit-form illumination area 20 on the pattern formation surface of the reticle 19 is set by the aperture of the visual field diaphragm 15.

[0025]

The reticle 19 is held on a reticle stage 21, and a moving mirror 22 is attached [which moves] in the X direction (the left-right direction within the plane of the page in Figure 1) and the Y direction (the direction perpendicular to the plane of the page in Figure 1) of the reticle stage 21. The reticle stage 21 and moving mirror 22 are supported so that they can move in the XY plane along a guide 23, and so that they can move at a uniform speed [?] [*unclear wording — Translator*] in the X direction. A driving device 26 which is used to perform micro-rotational movements, etc., for the purpose of correcting yawing and movements in the X and Y directions is connected to the reticle stage 21. Furthermore, the laser beam from a laser interferometer 24 fastened to the guide 23 is reflected by the moving mirror 22, so that the position of the reticle 19 in the X and Y directions and the amount of yawing of the reticle 19 are constantly measured by the laser interferometer 24. These measurement data are sent to a main control system 25. The main control system 25 controls the operation of the reticle 19 via the driving device 26, and controls the light emission operation of the pulsed laser light source 12 via a laser light source control device 34.

[0026]

The pulsed laser light IL passing through the pattern of the reticle 19 is conducted onto a wafer 28 via a projection optical system 27, and an image of the pattern on the reticle 19 within the illumination area 20 is reduced by a specified projection magnification β and focused on an exposure area 20P on the wafer 28 that is conjugate with the illumination area 20. The wafer 28 is held on a wafer holder 29 that is free to perform micro-rotational movements, and this wafer holder 29 is fastened to a wafer stage 30. The wafer stage 30 is constructed from an XY stage that positions the wafer 28 on a two-dimensional plane consisting of the X direction and Y direction, and a Z stage that positions the wafer 28 in the Z direction parallel to the optical axis of the projection optical system 27, etc. A moving mirror 31 which is used to reflect a laser beam from a laser interferometer 32 is fastened to the wafer stage 30, and this laser interferometer 32 constantly measures the position of the wafer 28 on the XY plane, and the amount of yawing of the wafer 28. These measurement data are sent to the main control system 25. The main control system 25 controls the operation of the wafer stage 30 via a driving device 33. Furthermore, a memory device 25a is connected to the main control system 25.

[0027]

Figure 2 (a) shows the rectangular slit-form illumination area 20 on the reticle 19; this illumination area 20 contacts the inside of the perimeter of a circular area that is conjugate with the maximum exposure field of the projection optical system 27. The length of this area in the Y direction, which is the direction of length of the area, is (L + 2M), and the width of this area in the X direction, which is the direction of the narrower width of the area, is D. As a result of the reticle 19 being scanned in the X direction of this width D, the pulsed laser light within the illumination area 20 successively illuminates a broader pattern area on the reticle 19. Furthermore, as is shown in Figure 2 (b), the illuminance distribution S in the Y direction within the illumination area 20 is constant in an area of length L in the center, and drops more or less linearly to 0 in respective areas 20a and 20b of length M on both sides. In other words, the illuminance distribution S in the Y direction perpendicular to the direction of relative scanning within the illumination area 20 has a trapezoidal shape. An illuminance distribution with such a trapezoidal shape can be obtained by placing the direction of length in a defocused state in the aperture of the visual field diaphragm 15 in Figure 1. Alternatively, a trapezoidal illuminance distribution can also be obtained by installing an ND filter with a linearly varying transmissivity distribution in the visual field diaphragm 15 or illumination-optimizing optical system 13.

[0028]

Figure 3 shows the reticle 19 in Figure 1. In this Figure 3, a pattern area 35 with a width of LT in the Y direction is formed on the pattern formation surface of the reticle 19, and a circuit pattern that is to be transferred to the wafer is formed in this pattern area 35. Furthermore, a prohibited zone 36 consisting of [an area with] a width of M or greater in which light is blocked is formed to the outside of the pattern area 35 in the Y direction. In the present example, the pattern in the pattern area 35 is transferred onto the wafer by scanning the pattern area 35 twice in the X direction with a slit-form illumination area 20. Furthermore, the pattern of more or less the right-half area 35a is transferred onto the wafer by the first scan, and the pattern of more or less the left-half area 35b is transferred onto the wafer by the second scan.

[0029]

In this case, the system is arranged so that the left end portion of the area 35a and the right end portion of the area 35b overlap in the Y direction in a connecting area 35c with a width of M, and so that this connecting area 35c is scanned by the area 20a or 20b in which the illuminance of the illumination area 20 gradually drops. As a result, the illuminance distribution in the connecting area 35c is uniform, and positional deviation of the transferred pattern is prevented. Furthermore, in order to insure a constant illuminance within the pattern area 35, the system is arranged so that areas that are scanned by the areas 20a and 20b in which the illuminance of the illumination area 20 gradually drops are not generated in the end portions of the pattern area 35 with respect to the Y direction. Since the width in the Y direction of the area in which the illuminance is constant within the illumination area 20 is L, and the respective widths in the Y direction of the areas 20a and 20b in which the illuminance gradually drops to zero are M,

the width LT of the pattern area 20 [*sic; error for "35"? — Translator*] in the Y direction is as follows:

[Numerical Expression 3]

$$LT = 2 \bullet L + M$$

[0030]

Generally, in a case where the pattern of the pattern area 35 is transferred onto the wafer by scanning the pattern area 35 n times in the X direction with the illumination area 20, the generation of areas illuminated only by the area 20a or 20b in which the illuminance gradually drops can be prevented by determining the width LT of the pattern area 35 in the Y direction as follows:

[Numerical Expression 4]

$$LT = n \bullet T + (n - 1) \bullet M$$ [?] [*poor legibility in original — Translator*]

[0031]

Figure 4 (a) shows the rectangular slit-form exposure area 20P on the surface of the wafer 28 in Figure 1. This exposure area 20P is conjugate with the illumination area 20 on the reticle 19 in Figure 2 (a). In this case, since the projection magnification of the projection optical system 27 is β, the width of the exposure area 20P in the X direction is $\beta \bullet D$, and the width of the exposure area 20P in the Y direction is $\beta \bullet (L + 2M)$. Furthermore, as is shown in Figure 4 (b), the illuminance S drops more or less linearly to zero in areas 20aP and 20bP with respective widths of $\beta \bullet M$ in the Y direction located within the exposure area 20P on both sides. Moreover, since the wafer 28 is scanned in the X direction with respect to the exposure area 20P when slit scanning exposure is performed, the illuminance distribution of the exposure area 20P in the Y direction perpendicular to the direction of relative scanning also has a trapezoidal shape.

[0032]

Next, the conditions for the width $\beta \bullet D$ of the exposure area 20P in the X direction, which is the direction of relative scanning, will be described. In this case, where T is the period (i.e., the reciprocal of the light emission frequency f) of the pulsed light emission of the pulsed laser light source 12 in Figure 1, and ΔL is the distance for which the wafer 28 is scanned in the X direction during one period T when slit scanning exposure is performed, the width $\beta \bullet D$ of the exposure area 20P in the X direction is set at an integral multiple of the distance ΔL. Furthermore, assuming that the scanning speed of the wafer 28 in the X direction is $\beta \bullet V$, the distance ΔL is $T \bullet \beta \bullet V$. In other words, the following equation holds true when m is an integer of 1 or greater.

[Numerical Expression 5]

$$\beta \bullet D = m \bullet \Delta L = m \bullet T \bullet \beta \bullet V$$

[0033]

In Figure 4 (a), a case is illustrated in which $\beta \bullet D = 4 \bullet \Delta L$. In this case, for example, an exposure point Q0 which is present in the edge portion of the exposure area 20P at the point in time where pulsed light emission occurs is illuminated by three pulses of pulsed laser light within the interior portion of the exposure area 20P, and is illuminated by two pulses of pulsed laser light in the edge portions of the exposure area 20P. Furthermore, where ΔE is the energy with which an exposure point is illuminated by one pulsed light emission in the interior portion of the exposure area 20P, the exposure point Q0 is illuminated by an energy equal to $4 \bullet \Delta E$ ($= \Delta E/2 + 3 \bullet \Delta E + \Delta E/2$). Furthermore, for example, an exposure point Q1 on the wafer that is positioned to the inside of the edge portion of the exposure area 20P at the point in time where pulsed light emission occurs is also illuminated by an energy of $4 \bullet \Delta E$, and an exposure point Q2 on the wafer that is positioned to the outside of the edge portion of the exposure area 20P at the point in time where pulsed light emission occurs is similarly illuminated by an energy of $4 \bullet \Delta E$. Thus, in the present example, all of the exposure points scanned by the exposure area 20P on the wafer are illuminated by the same m pulses of pulsed laser light. Accordingly, the illuminance distribution is constant at the exposure points scanned by the area in which the illuminance distribution is constant within the exposure area 20P.

[0034]

Furthermore, in the case of the exposure points that are scanned once by the areas 20aP and 20bP on both sides of the exposure area 20P, the energy by which the exposure points are illuminated is diminished even if the number of pulses by which the exposure points are illuminated is [the same] m pulses. However, as will be described later, the system in the present example is arranged so that the connecting area during stitching is scanned twice by the areas 20aP and 20bP; accordingly, the energy by which all of the exposure points in the connecting area are illuminated is $m \bullet \Delta E$. Consequently, the amount of illuminating energy is the same at all of the exposure points on the wafer, so that irregular illuminance is eliminated.

[0035]

Next, one example of the stitching and slit scanning exposure operation of the present [working] example will be described. First, in Figure 1, in a state in which the slit-form illumination area 20 on the reticle 19 is illuminated by the [above-mentioned] pulsed laser light IL, the reticle 19 is scanned at a constant speed V in the X direction via the driving device 26 and reticle stage 21. In synchronization with this, the wafer 28 is scanned at a constant speed $\beta \bullet V$ in the X direction via the driving device 33 and wafer stage 30. When the reticle 19 and wafer 28 are thus scanned, the difference between the measurement value of the laser interferometer 24 and a value obtained by multiplying the measurement value of the laser interferometer 32 by the

projection magnification β when (for example) a specified alignment mark on the reticle 19 and a specified alignment mark on the wafer 28 are aligned is stored in memory as a reference value, and the respective operations of the driving devices 26 and 33 are controlled so that the difference between the measurement value of the laser interferometer 24 and the [above-mentioned] value obtained by multiplying the measurement value of the laser interferometer 32 by the projection magnification β equals the reference value stored in memory beforehand. Accordingly, the reticle 19 and wafer 28 are scanned in the direction of narrow width with respect to the illumination area 20 and exposure area 20P in a state in which the reticle 19 and wafer 28 are always stationary with respect to each other in a specified relationship.

[0036]

As a result, as is shown in Figure 3, the slit-form illumination area 20 on the side of the reticle 19 relatively scans the area 35a on the right side of the pattern area 35 along the trace 37. Furthermore, as is shown in Figure 5 (a), the slit-form exposure area 20P on the side of the wafer 28 relatively scans the area 40a on the left side of the exposed area 40 corresponding to the pattern area 35 along the trace 37P.

[0037]

Next, at the point in time where the first slit scanning exposure is completed, the reticle 19 is caused to move in the Y direction by the stitching shown in Figure 3, so that the illumination area 20 is caused to move to the upper left of the pattern area 35 along the trace 38. Furthermore, as is shown in Figure 5 (a), the wafer 28 is caused to move in the –Y direction, so that the slit-form exposure area 20P is caused to move to the lower right of the exposed area 40 along the trace 38P. Afterward, the second slit scanning exposure is performed by scanning the reticle 19 at a speed of V in the X direction, and scanning the wafer 28 at a speed of β • V in the –X direction. As a result, as is shown in Figure 3, the slit-form illumination area 20 on the side of the reticle 19 relatively scans the area 35b on the left side of the pattern area 35 along the trace 39. Furthermore, as is shown in Figure 5 (a), the slit-form exposure area 20P on the side of the wafer 28 relatively scans the area 40b on the right side of the exposed area 40 corresponding to the pattern area 35 along the trace 39P.

[0038]

Furthermore, as is shown in Figure 3, the system is arranged so that in the first and second scans, an overlapping exposure is performed by the left-hand area 20a in which the illuminance of the illumination area 20 drops and the right-hand area 20b in which this illuminance drops, in the connecting area 35c located in the central portion (with respect to the Y direction) of the pattern area 35 on the reticle 19. As a result, as is shown in Figure 5 (a), an overlapping exposure is performed by the right-hand area 20aP in which the illuminance of the slit-form exposure area 20P drops and the left-hand area 20bP in which this illuminance drops, in the connecting area 40c located in the central portion (with respect to the Y direction) of the exposed area 40 on the wafer 28. For example, in the case of the exposure point Q3 located within the connecting area

40c, the illuminance during the first exposure is the illuminance SA shown in Figure 5 (b), and the illuminance during the second exposure is the illuminance SB. Since the illuminance distribution in the Y direction in areas 20aP and [20]bP drops linearly to zero in a symmetrical manner, the illuminance produced by the sum of the illuminance SA and illuminance SB is equal to the illuminance SC in the area where the illuminance of the exposure area 20P is constant.

[0039]

Furthermore, as has already been described, all of the exposure points scanned once by the exposure area 20P are illuminated by m pulses of pulsed laser light. Accordingly, the exposure point Q3 within the connecting area 40c is illuminated with an amount of energy equal to that of exposure points in the non-connecting area by two scans of the exposure area 20P, so that the illuminance distribution is made uniform at all exposure points on the wafer 28. Furthermore, at exposure points located within the connecting area 40c, the number of pulses with which the exposure points are illuminated by two scans is 2m, which is twice the number of pulses [received by] exposure points in the non-connecting area. Accordingly, the effects of the spectrum and variation in energy between individual pulses of the pulsed laser light are especially reduced in the connecting area 40c. In concrete terms, in regard to variation in the illuminance caused by variation in energy between individual pulses of the pulsed laser light, the variation in the connecting area 40c can be kept to $1/2^{1/2}$ of the variation in the non-connecting area.

[0040]

Next, in the present working example, when the area 40a on the wafer 28 shown in Figure 5 (a) is subjected to slit scanning exposure, the relative positions of the reticle 19 and wafer 28 are monitored by the laser interferometers 24 and 32, and the amount of relative positional deviation of the reticle 19 and wafer 28 is stored as mechanical control errors in the memory device 25a shown in Figure 1. Specifically, if an image of an arbitrary exposure point on the wafer 28 is formed by illumination with m pulses of pulsed laser light as a result of the first scan, the amount of relative positional deviation in the X direction is monitored in synchronization with the respective pulsed light emissions. The mean positional deviation $<\Delta x>$ can be calculated by means of the following operation, where Δx_1 is relative positional deviation in the X direction for each pulse, and Σ expresses the sum of 1 through m for the subscripts i.

[Numerical Expression 6]

$$<\Delta x> = \Sigma\Delta x_1/m$$

[0041]

Similarly, the amount of relative positional deviation Δy_1 of the reticle 19 and wafer 28 in the Y direction perpendicular to the X direction constituting the direction of relative scanning, and the rotational error of the reticle 19 and wafer 28, are also stored in the memory device 25a. Accordingly, if the storage capacity for one positional deviation amount Δx_1 is designated as ΔM,

then a capacity of $\Delta M \times m$ is sufficient as the storage capacity of the memory device 25a; however, if (for example) the relative positional deviation amounts in positions that are close to each other are averaged, the number of relative positional deviation amounts, etc., that are stored can be reduced. The relative positional error and rotational error thus stored in the memory device 25a are the cause of so-called "in-shot distortion" in the connecting area 40c on the wafer 28.

[0042]

Next, when the area 40b in Figure 5 (a) is exposed by the second scan, the main control system 25 controls the respective operations of the reticle stage 21 and wafer stage 30 via the driving devices 26 and 33 so that these operations are caused to conform to the relative positional error and rotational error read out from the memory device 25a. As a result, the overlapping precision of the pattern in the connecting area 40c on the wafer 28 is high. Ordinarily, furthermore, if the respective positioning precision values of the reticle stage 21 and wafer stage 30 in the X and Y directions are Δx and Δy, the respective overlapping errors in the connecting area 40c are $2^{1/2}\Delta x$ and $2^{1/2}\Delta y$. In the method of the present [working] example, on the other hand, since the positional relationship during the exposure of the next area 40b is corrected in accordance with the shot distortion occurring during the exposure of the initial area 40a (i. e., since the positions of the reticle 19 and wafer 28 are controlled so that the shot distortion is the same), the overlapping errors are only Δx and Δy.

[0043]

Next, the method used to expose the entire exposure surface of the wafer 28 will be described. First, in a case where the method of Figure 5 (a) is used, successive adjacent areas 40-1a, 40-1b, 40-2a, 40-2b, ..., 40-4b and 40-4a are respectively exposed by slit scanning exposure as shown in Figure 6. However, in the method shown in Figure 6, the direction of scanning is the opposite of that shown in Figure 5 (a). Furthermore, the circuit pattern of the pattern area 35 on the reticle 19 is respectively transferred to two scanning areas, e. g., areas 40-1b and 40-1a. In this method, the scanning direction of the pattern area 35 of the reticle 19 within the conjugate image on the wafer 28 is reversed. Furthermore, this scanning method is advantageous in that the pattern of the pattern area 35 can be transferred onto the wafer 28 in a short time, so that [the transfer] tends to be unaffected by expansion, etc., of the wafer 28. On the other hand, there is a danger that the precision of the connecting area, which depends on the characteristics of the scanning direction, will deteriorate, so that the movement of the reticle 19 corresponding to the trace 38 in the Y direction of the illumination area 20 shown in Figure 3 must be performed at a high speed.

[0044]

Next, as is shown in Figure 7, there is also a method in which only the right-half area 35a (for example) of the pattern area 35 of the reticle 19 is first continuously exposed in the corresponding area on the wafer 28, after which only the left-half area 35b of the pattern area 35

is continuously exposed in the corresponding area on the wafer 28. Specifically, in this method, the areas 40-1b, 40-2b, ... and 40-4b on the wafer 28 are first exposed as shown in Figure 7 (a); then, as is shown in Figure 7 (b), the areas 40-1a, 40-2a, ... and 40-4a on the wafer 28 are exposed parallel to the trace shown in Figure 7 (a). In this method, the scanning direction of the slit-form exposure area 20P is the same in two exposed areas (e. g., areas 40-1b and 40-1a) on the wafer 28 corresponding to the pattern area 35 of the reticle 19. As a result, the overlapping precision in the connecting area 40c may be improved in some cases.

[0045]

Next, since a refractive optical system is used as the projection optical system 27 in the above working example, the illumination area on the reticle 19 is a rectangular illumination area 20 as shown in Figure 2 (a). On the other hand, especially in cases where the wavelength of the exposing light is shortened, it is advantageous from the standpoint of aberration, etc., to use a projection optical system that is constructed from a reflective-refractive optical system using concave mirrors, etc. Furthermore, since the aberration is smaller in areas removed from the optical axis in the case of concave mirrors, etc., the slit-form illumination area on the reticle 19 is a circular arc form illumination area 41 as shown in Figure 8 (a) in cases where a reflective-refractive optical system is used. In this case as well, the width D of the illumination area 41 in the direction of relative scanning is constant, and, if the direction of length of the illumination area 41 that is perpendicular to the direction of relative scanning is the Y direction, then the illuminance distribution of the illumination area 41 in the Y direction has a trapezoidal shape as shown in Figure 8 (b). Specifically, in the areas 41a and 41b on both sides of the illumination area 41 in the Y direction, the illuminance distribution drops linearly to zero. By setting the illuminance distribution in this manner, it is possible to reduce irregularities in the illuminance of the connecting area during stitching, in the same manner as in the working example shown in Figure 1.

[0046]

Next, another working example of the present invention will be described with reference to Figure 9. In the present working example, the present invention is applied to a system in which the wafer is scanned by a regular hexagonal exposure area 3 as described with reference to Figure 1.

Figures 9 (a) and 9 (b) show the connecting area 4 on the wafer when stitching is performed in the present working example. In these Figures 9 (a) and 9 (b), the illuminance distribution is uniform in the regular hexagonal exposure area 3; however, pulsed laser light is used as the exposing light. Furthermore, if the direction of relative scanning is oriented in the X direction and –X direction, then the two opposite sides of the exposure area 3 with a spacing of W are parallel to the Y direction, which is the direction of stitching. In this case as well, assuming that the distance that the wafer moves in the X direction or –X direction during one period of pulsed light emission in slit scanning exposure is ΔL, the spacing W is set as follows using an integer m of 1 or greater.

[Numerical Expression 7]

$$W = m \bullet \Delta L$$

[0047]

A case in which m = 8 is illustrated in Figures 9 (a) and 9 (b). Here, an exposure point P0 in the non-connecting area on the wafer is always illuminated by eight pulses of energy as a result of one scan.

Furthermore, in the present working example, the position of the wafer in the X direction at the time of pulsed light emission by the pulsed laser light source is the same when the wafer is scanned in the X direction with respect to the exposure area 3 and when the wafer is scanned in the –X direction with respect to the exposure area 3. For example, in Figure 9 (a), when the exposure point P9 within the connecting area 4 on the wafer is scanned in the X direction with respect to the exposure area 3, i.e., when the exposure point P9 scans area 3a with two equal sides and three angles on the right side of the exposure area 3, the position of the exposure point P9 in the X direction at the time that pulsed light emission is performed is designated as position 8. Then, if the position of the exposure point P9 in the X direction at the time that pulsed light emission is performed when the exposure point P9 is scanned in the –X direction with respect to the exposure area 3 in the second scan, i. e., when the exposure point P9 scans the area 3b with two equal sides and three angles on the left side of the exposure area 3, is designated as position 42, this means that position 42 and position 8 coincide. In the case of Figure 9 (a), there are five positions 8 within the area 3a, and three positions 42 within the area 3b; accordingly, the exposure point P9 is illuminated by a total of eight pulses of energy as a result of two slit scanning exposures.

[0048]

Furthermore, in Figure 9 (b), the timing of the pulsed light emission is shifted by $\Delta L/2$ in the X direction compared to the case shown in Figure 9 (a). In Figure 9 (b), the system is arranged so that the position 43 of the exposure point P9 in the X direction at the time that pulsed light emission occurs when the exposure point P9 scans the area 3b with two equal sides and three angles on the left side of the exposure area 3 in the second scan is equal to the position 10 of the exposure point P9 in the X direction at the time that pulsed light emission occurs when the exposure point P9 scans the area 3a with two equal sides and three angles on the right side of the exposure area 3. In the case of Figure 9 (b), there are four positions 10 within the area 3a, and four positions 43 within the area 3b. Accordingly, the exposure point P9 is illuminated by a total of eight pulses of energy as a result of two slit scanning exposures. Generally, in the present [working] example, each exposure point in the connecting area 4 is illuminated by eight pulses of energy as in the case of the exposure point P0 in the non-connecting area, so that there is no irregularity in the illuminance. Furthermore, in the above working examples, a stitching operation using a single reticle was described; however, it would also be possible to place a plurality of reticles on the same reticle stage, and to arrange the system so that scanning exposure is repeated

with the reticles being changed at the time of stitching.

[0049]

Furthermore, the present invention is not limited to the working examples described above; it goes without saying that various constructions may be adopted within limits that involve no departure from the gist of the present invention.

[0050]

[Merits of the Invention]

In the first projection optical apparatus of the present invention, when exposure is performed by means of a stitching and slit scanning exposure system using a pulsed emission type light source, each point in the connecting area on the photosensitive substrate is exposed by the same illuminance as in the non-connecting area as a result of being subjected to slit scanning exposure twice. Accordingly, there is an advantage in that irregularities in illuminance in the connecting area on the photosensitive substrate can be reduced.

[0051]

Furthermore, in a case where a memory means is provided which stores the relative positional error of the mask and photosensitive substrate when the mask and photosensitive substrate are relatively scanned in synchronization in a specified direction of the illumination area illuminated by the exposing light, the overlapping error in the connecting area can be reduced by storing the relative positional error occurring in the first scan in the connecting area in memory, and by performing positional control during the second scan in the connecting area so that [the positions] conform to this relative error.

Furthermore, as a result of the width LT of the transfer pattern formed on the mask in the second direction of the illumination area illuminated by the exposing light being set at $\{n \bullet L + (n - 1) \bullet M\}$, where L is the length of the area in which the illuminance distribution is constant in the second direction of the illumination area with a trapezoidal illuminance distribution illuminated by the exposing light on the mask, and M indicates the lengths of the areas in which the illuminance gradually drops on both sides of the area with a trapezoidal illuminance distribution, the transfer pattern on the mask is always illuminated by a constant illuminance.

[0052]

Furthermore, in cases where a mask moving means is provided which causes relative movement of the mask in the second direction of the illumination area illuminated by the exposing light, stitching can be performed on the mask side as well.

Next, in the second projection optical apparatus [*Translator's note: original actually*

reads "illumination optical apparatus", but this appears to be an error.] of the present invention, the positions of pulsed light emission during the first scan and the positions of pulsed light emission during the second scan are equal in the connecting area; accordingly, the illuminance at each exposure point in the connecting area is equal to the illuminance at respective exposure points in the non-connecting area, so that irregular illuminance is reduced.

[Brief Description of the Drawings]

[Figure 1] Figure 1 is a structural diagram which illustrates one working example of the projection optical apparatus of the present invention.

[Figure 2] Figure 2 (a) is a plan view which illustrates the slit-form illumination area on the reticle 19 in Figure 1. Figure 2 (b) is a distribution graph which shows the illuminance distribution in this illumination area.

[Figure 3] Figure 3 is a plan view which illustrates the pattern on the reticle in the above-mentioned working example.

[Figure 4] Figure 4 (a) is a plan view which illustrates the slit-form exposure area on the wafer in the above-mentioned working example. Figure 4 (b) is a distribution graph which shows the illuminance distribution in this exposure area.

[Figure 5] Figure 5 (a) is a plan view which illustrates the exposed area on the wafer. Figure 5 (b) is a distribution graph which shows the illuminance distribution in this exposed area.

[Figure 6] Figure 6 is a plan view which illustrates one example of the trace of the slit scanning exposure on the wafer in the above-mentioned working example.

[Figure 7] Figure 7 is a plan view which illustrates another example of the trace of the slit scanning exposure on the wafer in the above-mentioned working example.

[Figure 8] Figure 8 (a) is a plan view which illustrates a modification of the illumination area on the reticle. Figure 8 (b) is a distribution graph which shows the illuminance distribution in this modification of the illumination area.

[Figure 9] Figure 9 (a) is an enlarged plan view which illustrates one example of the positional relationship of pulsed light emission in another working example of the present invention. Figure 9 (b) is an enlarged plan view which illustrates another example of the positional relationship of pulsed light emission in this other working example of the present invention.

[Figure 10] Figure 10 (a) is a plan view which shows the conditions of relative scanning of the illumination area on the reticle when stitching and slit scanning exposure is performed using a conventional projection exposure apparatus equipped with a continuous emission type light

source. Figure 10 (b) is a plan view corresponding to Figure 10 (a) which shows the conditions of relative scanning of the exposure area on the wafer.

[Figure 11] Figure 11 is a line drawing which is used to illustrate the irregular illuminance seen on the photosensitive substrate when a pulsed emission type light source is used in a case where stitching and slit scanning exposure is performed in a regular hexagonal exposure area.

[Explanation of Symbols]

12	Pulsed laser light source
13	Illumination-optimizing optical system
15	Visual field diaphragm
16	Relay lens
18	Condenser lens
19	Reticle
20	Rectangular slit-form illumination area on reticle
20P	Rectangular slit-form exposure area on wafer
21	Reticle stage
23	Guide
24, 32	Laser interferometers
25	Main control system
26, 33	Driving devices
28	Wafer
30	Wafer stage
34	Laser light source control device
25	Pattern area
40	Exposed area

[Key to Figure 1: 12 Pulsed laser light source, 25 Main control system, 25a Memory device, 34 Laser light source control device.]

[Translators' note: the remaining figures do not require keys.]

[Document Title] Abstract

[Abstract]

[Object] [The object of the present invention is] to reduce illuminance irregularity in the connecting area exposed by being scanned twice [by stitching] on the photosensitive substrate in cases where the light source is a pulsed emission type light source [in a projection optical apparatus] in which exposure is performed using a stitching and slit scanning exposure system.

[Constitution] The exposure area on the wafer is formed as a rectangular slit-form exposure area 20P, and the wafer is exposed by being scanned in the X direction or –X direction with respect to the exposure area 20P. The illuminance distribution S in the Y direction of the exposure area 20P has a trapezoidal shape, and the system is arranged so that in the connecting area on the wafer, exposure is performed by means of an area 20aP in which the illuminance gradually drops on the right side of the exposure area 20P and an area 20bP in which the illuminance gradually drops on the left side [of the exposure area 20P].

[Selected Figures] Figure 4 [?] [*poor legibility – Translator*]

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【手数料の表示】

　【納付方法】　予納

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【発明の名称】 投影光学装置

【特許請求の範囲】

【請求項１】 露光光をパルス発光するパルス光源と、前記露光光で転写用のパターンが形成されたマスクを均一な照度で照明する照明光学系と、前記マスク上の前記露光光による照明領域を設定する視野絞りと、前記マスクの転写用のパターンの像を感光基板上に投影する投影光学系と、前記露光光による照明領域の所定の方向に相対的に前記マスク及び前記感光基板を同期して走査する相対走査手段とを有し、

前記マスク上の前記露光光による照明領域よりも広い領域の転写用のパターンの像を前記感光基板上に露光する投影光学装置において、

前記露光光による照明領域の前記所定の方向に交差する第２の方向に相対的に前記感光基板を移動させる基板移動手段と、

前記露光光による照明領域の前記第２の方向の照度分布を台形状にする照度分布設定手段とを設け、

前記感光基板を前記露光光による照明領域の前記第２の方向にずらしながら、前記露光光による照明領域の前記所定の方向に前記感光基板を相対的に複数回走査して、前記マスク又は該マスクと交換されたマスクの転写用のパターンの像を前記感光基板上に露光する事を特徴とする投影光学装置。

【請求項２】 前記露光光による照明領域の前記所定の方向に相対的に前記マスク及び前記感光基板を同期して走査する際の、前記マスクと前記感光基板との相対的な位置の誤差を記憶する記憶手段を設けた事を特徴とする請求項１記載の投影光学装置。

【請求項３】 前記マスク上の前記露光光による照度分布が台形状の照明領域の前記第２の方向の、照度分布が一定の領域の長さをＬ、前記照度分布が台形状の領域の両側の照度が次第に小さくなる領域の長さをそれぞれＭとして、前記マスク上に形成される転写用のパターンの前記露光光による照明領域の前記第２の方向の幅をＬＴとした場合、１以上の整数ｎを用いて

$$LT = n \cdot L + (n-1) \cdot M$$

が成立するように、前記マスク上に形成される転写用のパターンの幅ＬＴを定めた事を特徴とする請求項１又は２記載の投影光学装置。

【請求項４】　前記露光光による照明領域の前記第２の方向に相対的に前記マスクを移動させるマスク移動手段を設けた事を特徴とする請求項１、２又は３記載の投影光学装置。

【請求項５】　露光光をパルス発光するパルス光源と、前記露光光で転写用のパターンが形成されたマスクを均一な照度で照明する照明光学系と、前記マスク上の前記露光光による照明領域を設定する視野絞りと、前記マスクの転写用のパターンの像を感光基板上に投影する投影光学系と、前記露光光による照明領域の所定の方向に相対的に前記マスク及び前記感光基板を同期して走査する相対走査手段とを有し、

前記マスク上の前記露光光による照明領域よりも広い領域の転写用のパターンの像を前記感光基板上に露光する投影光学装置において、

前記露光光による照明領域の前記所定の方向に交差する第２の方向に相対的に前記感光基板を移動させる基板移動手段と、

前記パルス光源がパルス発光するときの、前記所定の方向に共役な方向の前記感光基板の位置を検出して記憶する発光位置記憶手段と、

前記パルス光源のパルス発光の開始時点を制御する発光制御手段とを設け、

前記感光基板を前記露光光による照明領域の前記第２の方向にずらしながら、前記露光光による照明領域に対して前記所定の方向に前記マスク又は該マスクと交換されたマスク及び前記感光基板を相対的に複数回走査して、前記マスク又は該マスクと交換されたマスクの転写用のパターンの像を前記感光基板上に露光する際に、前記相対的な走査のそれぞれにおいて前記パルス光源がパルス発光するときの前記感光基板の前記所定の方向と共役な方向の位置が同　になるようにした事を特徴とする投影光学装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】

本発明は、例えば半導体集積回路又は液晶表示素子等をリソグラフィ工程で製

造する際に使用される投影光学装置に関し、特にパルス発光する光源を用いて所謂スティッチング及びスリットスキャン露光方式で露光を行う投影露光装置に適用して好適な投影光学装置に関する。

【０００２】

【従来の技術】

半導体素子又は液晶表示素子等をリソグラフィ工程で製造する際に、露光光のもとでフォトマスク又はレチクル（以下「レチクル」と総称する）のパターン像を投影光学系を介して感光基板上に投影する投影露光装置が使用されている。斯かる装置として、例えば特公昭４６－３４０５７号公報に開示されているように、スティッチング及びスリットスキャン露光方式の投影露光装置が知られている。このスティッチング及びスリットスキャン露光方式では、レチクル上の所定形状の照明領域に対して相対的に所定の第１の方向にレチクル及び感光基板を同期して走査することにより、感光基板上の第１列目の領域への露光が行われる。

【０００３】

その後、そのレチクルを交換するか、又はそのレチクルをその照明領域の第１の方向に垂直な第２の方向に所定量だけ移動して、その感光基板をその照明領域の第２の方向に共役な方向に横ずれ（スティッチング）させる。そして、再びレチクル上の所定形状の照明領域に対して相対的に第１の方向にレチクル及び感光基板を同期して走査することにより、感光基板上の第２列目の領域への露光が行われる。これにより、投影光学系の露光フィールドよりも広い感光基板上の領域にレチクルのパターンを露光することができる。

【０００４】

図１０（ａ）は、従来のスティッチング及びスリットスキャン露光方式の投影露光装置におけるレチクル上の照明領域を示し、この図１０（ａ）において、位置Ａを中心とする正６角形状の照明領域１に照明光学系からの露光光が照射されている。また、位置Ａの照明領域１に対してレチクルを－Ｘ方向に一定速度Ｖで走査することにより、照明領域１はレチクル上を軌跡２Ａに沿って相対的に移動して位置Ｂに達する。この状態でレチクルをＹ方向に移動することにより、照明領域１はレチクル上を軌跡２Ｂに沿って相対的に移動して位置Ｃに達する。その

後、レチクルをX方向に一定速度Vで走査することにより、照明領域1はレチクル上を軌跡2Cに沿って相対的に移動する。

【0005】

図10（b）は、従来のスティッチング及びスリットスキャン露光方式の投影露光装置における感光基板としてのウエハ上の被露光領域を示し、この図10（b）において、位置APを中心とする正6角形状の露光領域3がレチクル上の位置Aの照明領域1と共役な領域である。正6角形状の露光領域3は2辺がY方向に平行になっており、正6角形状の露光領域3の対向する2頂点の間隔をR、対向する2辺の間隔をWとすると、$W=3^{1/2}R/2$である。また、投影光学系によるレチクルからウエハへの投影倍率をβとして、位置APの露光領域3に対してウエハをX方向に一定速度β・Vで走査することにより、露光領域3はウエハ上を軌跡2APに沿って相対的に移動して位置BPに達する。この状態でウエハを－Y方向に距離3R／4だけ移動することにより、露光領域3はウエハ上を軌跡2BPに沿って相対的に移動して位置CPに達する。この動作がスティッチングである。その後、ウエハを－X方向に一定速度β・Vで走査することにより、露光領域3はウエハ上を軌跡2CPに沿って相対的に移動する。

【0006】

そして、軌跡2APに沿って相対移動する露光領域3と軌跡2CPに沿って相対移動する露光領域3とは、それぞれY方向の幅がR／4の2等辺3角形の領域が接続領域4で重なるように走査される。従って、接続領域4では2回露光が行われる。このように接続領域4を設けるのは、軌跡2APに沿って相対移動する露光領域3により露光されるパターンと、軌跡2CPに沿って相対移動する露光領域3により露光されるパターンとの間に位置ずれが生じないようにするためである。また、正6角形状の露光領域3の2等辺3角形の領域が重なるようにすることにより、次に示すように、ウエハ上の照度分布が均一化される。

【0007】

従来は露光光の光源としては、一般に水銀灯のように連続発光の光源が使用されていたため、ウエハ上の接続領域4中の露光点P1は、軌跡2APに沿って相対移動する露光領域3の領域5Aで連続的に露光され、軌跡2CPに沿って相対

移動する露光領域３の領域６Ａで連続的に露光される。それら領域５Ａ及び領域６ＡのＸ方向の長さの合計は露光領域３の幅Ｗと等しい。また、ウエハ上の接続領域４中の別の露光点Ｐ２は、軌跡２ＡＰに沿って相対移動する露光領域３の領域５Ｂで連続的に露光され、軌跡２ＣＰに沿って相対移動する露光領域３の領域６Ｂで連続的に露光され、それら領域５Ｂ及び領域６ＢのＸ方向の長さの合計はＷと等しい。また、軌跡２ＡＰに沿って相対移動する露光領域３だけに露光される非接続部の露光点Ｐ０では、Ｘ方向に幅Ｗの領域で連続的に露光される。従って、連続発光型の光源を使用した場合には、ウエハ上のどの露光点Ｐ０，Ｐ１，Ｐ２でも、照射される露光光の量は同じであり、照度分布は均一である。

【０００８】

【発明が解決しようとする課題】

ところで、最近は解像力をより向上するため、露光光の短波長化が求められている。現在実用化レベルにある光源の中で波長が比較的短いものは、ＡｒＦエキシマレーザー（波長：１９３ｎｍ）、ＫｒＦエキシマレーザー（波長：２４８ｎｍ）等のエキシマレーザー及び金属蒸気レーザー等である。しかしながら、エキシマレーザー光源及び金属蒸気レーザー光源はパルス発光（パルス発振）型であるため、その使用に際しては水銀灯のような連続発光の光源の場合とは違う配慮が必要である。

【０００９】

図１１（ａ）は正６角形状の露光領域３をパルスレーザー光源からのパルスレーザー光で照明する場合を示し、この図１１（ａ）において、露光領域３はウエハ上の投影光学系の円形の露光領域７の輪郭に内接する領域である。また、露光領域３の間隔がＷの対向する２辺がＹ方向に平行であり、露光領域３に対してＸ方向及び－Ｘ方向にウエハが相対的に走査されるものとする。この場合、パルスレーザー光のパルス毎のエネルギーのばらつきやスペックル等の影響を低減させるためには、ウエハ上の各露光点にパルスレーザー光を複数パルス露光する必要がある。そこで、露光領域３のＸ方向の幅がＷの領域により露光される露光点Ｐ０が、パルスレーザー光によりｍ回（ｍは１以上の整数）露光されるものとする。これは、パルス発光の１周期Ｔの間にウエハがＸ方向又は－Ｘ方向に走査され

る距離をΔLとして、ウエハの走査速度をβ・Vとすると、次の関係があればよい。

【数1】

$$W=m\cdot \Delta L-m\cdot T\cdot \beta\cdot V$$

【0010】

図11（a）はm＝8の場合を示しており、パルス発光があった時点に露光点P0が露光領域3のエッジ部に在るものとすると、露光点P0は露光領域3の内部で7回パルスレーザー光に露光され、エッジ部で2回パルスレーザー光に露光される。この場合、エッジ部で露光されるエネルギーは内部で露光されるエネルギーの1／2であるため、露光点P0には全体で8パルス分のエネルギーが照射される。そして、パルス発光時点で露光点P0がX方向のどの位置に在っても、露光点P0には全体で8パルス分のエネルギーが照射される。また、露光領域3の右側の2等辺3角形の領域3aが通過する露光点の中で、図11（a）に示す露光点P1～P8が2等辺3角形の領域3aを通過する距離は、それぞれ8・ΔL～1・ΔLである。従って、これら露光点P1～P8には、X方向に領域3aを通過する際にそれぞれ8パルス分～1パルス分のエネルギーが照射される。

【0011】

また、次にウエハのスティッチングを行ってから、露光領域3に対してウエハを－X方向に走査すると、露光点P1～P8にはそれぞれほぼ0パルス分～7パルス分のエネルギーが露光される。従って、露光点P1～P8でも、スティッチングにより2回スリットスキャン露光を行うことにより、それぞれ露光点P0と同様に8パルス分のエネルギーが露光される。

しかしながら、図11（a）の露光点P4と露光点P5との中間の露光点を図11（b）及び（c）の露光点P9とすると、この露光点P9では2回のスリットスキャン露光を行っても照射されるエネルギーがばらつくという不都合がある。即ち、図11（b）に示す場合には、ウエハを露光領域3の右側の2等辺3角形の領域3a内でX方向に走査する際に、露光点P9が位置8に在るときにパルス発光が行われ、スティッチング後にウエハを露光領域3の左の2等辺3角形の領域3b内でX方向に走査する際に、露光点P9が位置9に在るときにパルス発

光が行われる。従って、露光点Ｐ９には９パルス分のエネルギーが照射される。

【００１２】

一方、図１１（ｃ）に示す場合には、ウエハを露光領域３の右側の２等辺３角形の領域３ａ内でＸ方向に走査する際に、露光点Ｐ９が位置１０に在るときにパルス発光が行われ、スティッチング後にウエハを露光領域３の左の２等辺３角形の領域３ｂ内でＸ方向に走査する際に、露光点Ｐ９が位置１１に在るときにパルス発光が行われる。従って、露光点Ｐ９には７パルス分のエネルギーが照射される。従って、露光点Ｐ９には、パルス発光のタイミングにより７パルス分～９パルス分のエネルギーが照射されることになる。従って、ウエハ上の接続部４ではパルスレーザー光による照射エネルギーのむら、即ち照度むらが生じるという不都合がある。

【００１３】

本発明は斯かる点に鑑み、スティッチング及びスリットスキャン露光方式で露光を行う投影光学装置において、光源がパルス発光型の場合に感光基板上でスティッチングにより２回走査されて露光される接続部の照度むらを低減することを目的とする。

【００１４】

【課題を解決するための手段】

本発明による第１の投影光学装置は、例えば図１及び図２に示す如く、露光光をパルス発光するパルス光源（３４）と、その露光光で転写用のパターンが形成されたマスク（１９）を均一な照度で照明する照明光学系（１３，１６，１８）と、マスク（１９）上のその露光光による照明領域（２０）を設定する視野絞り（１５）と、マスク（１９）の転写用のパターンの像を感光基板（２８）上に投影する投影光学系（２７）と、その露光光による照明領域（２０）の所定の方向に相対的にマスク（１９）及び感光基板（２８）を同期して走査する相対走査手段（２５，２６，３３）とを有し、マスク（１９）上のその露光光による照明領域（２０）よりも広い領域の転写用のパターンの像を感光基板（２８）上に露光する投影光学装置を前提とする。

【００１５】

そして、本発明は、その露光光による照明領域（２０）のその所定の方向（Ｘ方向）に交差する第２の方向（Ｙ方向）に相対的に感光基板（２８）を移動させる基板移動手段（３０，３３）と、その露光光による照明領域（２０）のその第２の方向の照度分布を台形状（例えば図２（ｂ））にする照度分布設定手段（１３，１５）とを設け、感光基板（２８）をその露光光による照明領域（２０）のその第２の方向にずらしながら、その露光光による照明領域（２０）のその所定の方向に感光基板（２８）を相対的に複数回走査して、マスク（１９）又はこのマスクと交換されたマスクの転写用のパターンの像を感光基板（２８）上に露光するものである。

【００１６】

この場合、その露光光による照明領域（２０）のその所定の方向に相対的にマスク（１９）及び感光基板（２８）を同期して走査する際の、マスク（１９）と感光基板（２８）との相対的な位置の誤差を記憶する記憶手段（２５ａ）を設けることが望ましい。

また、例えば図３に示すように、マスク（１９）上のその露光光による照度分布が台形状の照明領域（２０）のその第２の方向の、照度分布が一定の領域の長さをＬ、その照度分布が台形状の領域の両側の照度が次第に小さくなる領域の長さをそれぞれＭとして、マスク（１９）上に形成される転写用のパターンのその露光光による照明領域（２０）のその第２の方向の幅をＬＴとした場合、１以上の整数ｎを用いて次の関係が成立するようにその幅ＬＴを定めることが望ましい。

【数２】

$$LT = n \cdot L + (n - 1) \cdot M$$

【００１７】

また、その露光光による照明領域（２０）のその第２の方向に相対的にマスク（１９）を移動させるマスク移動手段（２１，２６）を設けることが望ましい。

次に、本発明による第２の投影光学装置は、例えば図１に示すように、露光光をパルス発光するパルス光源（１２）と、その露光光で転写用のパターンが形成されたマスク（１９）を均一な照度で照明する照明光学系（１３，１６，１８）

と、マスク（１９）上のその露光光による照明領域（２０）を設定する視野絞り（１５）と、マスク（１９）の転写用のパターンの像を感光基板（２８）上に投影する投影光学系（２７）と、その露光光による照明領域（２０）の所定の方向に相対的にマスク（１９）及び感光基板（２８）を同期して走査する相対走査手段（２５，２６，３３）とを有し、マスク（１９）上のその露光光による照明領域（２０）よりも広い領域の転写用のパターンの像を感光基板（２８）上に露光する投影光学装置を前提とする。

【００１８】

そして、本発明は、その露光光による照明領域（２０）のその所定の方向（Ｘ方向）に交差する第２の方向（Ｙ方向）に相対的に感光基板（２８）を移動させる基板移動手段（３０，３３）と、パルス光源（１２）がパルス発光するときの、その所定の方向に共役な方向の感光基板（２８）の位置を検出して記憶する発光位置記憶手段（２５，２５ａ）と、パルス光源（１２）のパルス発光の開始時点を制御する発光制御手段（３４）とを設け、感光基板（２８）をその露光光による照明領域（２０）のその第２の方向にずらしながら、その露光光による照明領域（２０）に対してその所定の方向にマスク（１９）又はこのマスクと交換されたマスク及び感光基板（２８）を相対的に複数回走査して、マスク（１９）又はこのマスクと交換されたマスクの転写用のパターンの像を感光基板（２８）上に露光する際に、例えば図９に示すように、その相対的な走査のそれぞれにおいてパルス光源（１２）がパルス発光するときの感光基板（２８）のその所定の方向と共役な方向（Ｘ方向）の位置が同一になるようにしたものである。

【００１９】

【作用】

斯かる本発明の第１の投影光学装置によれば、マスク（１９）上の露光光による照明領域（２０）のその所定の方向、即ち相対走査の方向に交差する第２の方向の照度分布は台形状である。その結果、図５に示すように、感光基板（２８）上のその照明領域（２０）に共役な露光領域（２０Ｐ）のその第２の方向（Ｙ方向）の照度分布も台形状である。この場合、露光領域（２０Ｐ）の相対走査の方向の幅を一定にすると、露光領域（２０Ｐ）により相対走査される感光基板（２

８）上のその第２の方向に並んだ各露光点は、それぞれ同じパルス数の露光光に照射される。

【００２０】

また、スティッチングにより感光基板（２８）上で露光領域（２０Ｐ）を横ずれさせる際には、図５に示すように、照度分布が次第に低下する領域（２０ａＰ，２０ｂＰ）が重なるようにする。これにより、例えばスティッチングにより２回走査される接続部（４０ｃ）に存在する露光点Ｑ３では、１回目の走査時の照度ＳＡと２回目の走査時の照度ＳＢとの和が、台形状の照度分布中の照度分布が一定の領域の照度ＳＣに等しくなる。従って、感光基板（２８）上の接続部（４０ｃ）上の任意の露光点での照度が非接続部の露光点の照度とほぼ等しくなり、照度むらが低減される。また、接続部（４０ｃ）ではパルス的な露光光の照射パルス数が非接続部でのパルス数の２倍になるため、パルス毎のばらつきに起因する照度むら及びスペックルの影響が特に低減されている。

なお、感光基板（２８）のスティッチングを行う際には、マスク（１９）のスティッチングを行う代わりにマスク（１９）を別のマスクと交換してもよい。

【００２１】

次に、その露光光による照明領域（２０）のその所定の方向に相対的にマスク（１９）及び感光基板（２８）を同期して走査する際の、マスク（１９）と感光基板（２８）との相対的な位置の誤差を記憶する記憶手段（２５ａ）を設けた場合には、例えば１回目のスリットスキャン露光の際のマスク（１９）と感光基板（２８）との相対的な位置ずれ量を記憶しておく。そして、スティッチング後の２回目のスリットスキャン露光時に、マスク（１９）と感光基板（２８）との位置ずれ量をその記憶した位置ずれ量に合わせることにより、接続部の重ね合わせ精度を向上することができる。

【００２２】

また、例えば図３に示すように、マスク（１９）上のその露光光による照度分布が台形状の照明領域（２０）のその第２の方向の、照度分布が一定の領域の長さをＬ、その照度分布が台形状の領域の両側の照度が次第に小さくなる領域の長さをそれぞれＭとして、マスク（１９）上に形成される転写用のパターン（３５

）のその露光光による照明領域（２０）のその第２の方向の幅をＬＴとする。この場合、スティッチングによりその照明領域（２０）をマスク（１９）上でｎ回走査して、マスク（１９）上のパターン（３５）を感光基板（２８）上に露光するものとすると、その照明領域（２０）の接続部（３５ｃ）では、照度分布が次第に減少する長さＭの領域が重なる必要がある。しかしながら、パターン（３５）の両端部の照度分布を中央部と同程度に維持するためには、パターン（３５）の両端部ではその照度分布が減少する長さＭの領域は遮光されていることが望ましい。このため、パターン（３５）のその第２の方向の幅ＬＴは（数２）のようになる。

【００２３】

また、その露光光による照明領域（２０）のその第２の方向に相対的にマスク（１９）を移動させるマスク移動手段（２１，２６）を設け場合には、マスク（１９）に対してもスティッチングを行うことができる。

次に、本発明の第２の投影光学装置によれば、図９（ａ）に示すように、例えば正６角形状の露光領域（３）で感光基板（２８）上を走査する場合でも、接続領域（４）の任意の露光点Ｐ９に対する、１回目の走査時の露光光のパルス発光の位置（８）と２回目の走査時の露光光のパルス発光の位置（４２）とが等しい。図９（ａ）の場合には露光点Ｐ９には８パルス分のエネルギーが照射されている。また、図９（ｂ）の場合には、図９（ａ）の場合とはパルス発光のタイミングがずれているが、露光点Ｐ９に対する、１回目の走査時の露光光のパルス発光の位置（１０）と２回目の走査時の露光光のパルス発光の位置（４３）とが等しい。そして、図９（ｂ）の場合にも露光点Ｐ９には８パルス分のエネルギーが照射されている。即ち、スティッチングにより２回走査される接続部（４）では、２回の走査時のパルス発光の位置を同一に設定することで、常に一定のエネルギーが照射されることになり、照度むらが低減される。

【００２４】

【実施例】

以下、本発明による投影光学装置の一実施例につき図１～図７を参照して説明する。本実施例は、パルス発光型のレーザー光源を備えたスティッチング及びス

リットスキャン露光方式の投影露光装置に本発明を適用したものである。

図１は本実施例の投影露光装置の全体の構成を示し、この図１において、エキシマレーザー光源等のパルスレーザー光源１２から射出されたレーザービームＬＢは、ビームエクスパンダ、オプティカルインテグレータ、開口絞り及びリレーレンズ等よりなる照明最適化光学系１３に入射する。照明最適化光学系１３から射出された露光光としてのパルスレーザー光ＩＬが、偏向ミラー１４に反射されて視野絞り１５に入射する。視野絞り１５の開口を通過したパルスレーザー光ＩＬが、リレーレンズ１６、偏向ミラー１７及びコンデンサーレンズ１８を経て均一な照度でレチクル１９を照明する。視野絞り１５の配置面はレチクル１９のパターン形成面と共役であり、視野絞り１５の開口によりレチクル１９のパターン形成面のスリット状の照明領域２０の形状が設定される。

【００２５】

レチクル１９はレチクルステージ２１上に保持され、レチクルステージ２１のＸ方向（図１の紙面内の左右方向）及びＹ方向（図１の紙面に垂直な方向）に移動鏡２２が取り付けられ、レチクルステージ２１及び移動鏡２２はガイド２３に沿ってＸＹ平面内で移動できると共に、Ｘ方向に等速移動できるように支持されている。レチクルステージ２１にはＸ方向及びＹ方向への移動並びにヨーイング補正のための微小回転等を行うための駆動装置２６が接続されている。また、ガイド２３に対して固定されたレーザー干渉計２４からのレーザービームが移動鏡２２に反射され、レーザー干渉計２４によりレチクル１９のＸ方向及びＹ方向の位置並びにヨーイング量が常時計測され、これらの計測データが主制御系２５に供給されている。主制御系２５は、駆動装置２６を介してレチクル１９の動作を制御し、レーザー光源制御装置３４を介してパルスレーザー光源１２の発光動作を制御する。

【００２６】

レチクル１９のパターンを通過したパルスレーザー光ＩＬは、投影光学系２７を介してウエハ２８上に導かれ、照明領域２０と共役なウエハ２８上の露光領域２０Ｐに、照明領域２０内のレチクル１９のパターン像が所定の投影倍率βで縮小されて結像される。ウエハ２８は、微小回転自在なウエハホルダー２９上に保

持され、ウエハホルダー２９はウエハステージ３０上に固定されている。ウエハステージ３０は、Ｘ方向及びＹ方向よりなる２次元平面内でウエハ２８を位置決めするＸＹステージ、並びに投影光学系２７の光軸に平行なＺ方向にウエハ２８を位置決めするＺステージ等より構成されている。ウエハステージ３０上にレーザー干渉計３２からのレーザービームを反射するための移動鏡３１が固定され、レーザー干渉計３２はウエハ２８のＸＹ平面内での位置及びヨーイング量を常時計測し、この計測データが主制御系２５に供給されている。主制御系２５は、駆動装置３３を介してウエハステージ３０の動作を制御する。また、主制御系２５には記憶装置２５ａが接続されている。

【００２７】

図２（ａ）はレチクル１９上の矩形のスリット状の照明領域２０を示し、照明領域２０は、投影光学系２７の最大露光フィールドと共役な円形の領域の輪郭に内接し、長手方向であるＹ方向の長さが（Ｌ＋２Ｍ）であり、幅の狭い方向であるＸ方向の幅がＤである。この幅ＤのＸ方向にレチクル１９を走査することにより、照明領域２０内のパルスレーザー光がレチクル１９上のより広いパターン領域を順次照明する。また、図２（ｂ）に示すように、照明領域２０内のＹ方向の照度分布Ｓは、中央の長さＬの領域で一定であり、両側のそれぞれ長さＭの領域２０ａ，２０ｂでほぼ直線的に０に落ちている。即ち、照明領域２０内の相対走査の方向に垂直なＹ方向の照度分布Ｓは台形状である。このように、台形状の照度分布を得るには、図１の視野絞り１５の開口において、長手方向をデフォーカス状態にすればよい。又は、視野絞り１５又は照明最適化光学系１３中に、透過率分布が直線的に変化しているＮＤフィルター板等を配置することによっても、台形状の照度分布を得ることができる。

【００２８】

図３は図１中のレチクル１９を示し、この図３において、レチクル１９のパターン形成面にＹ方向の幅がＬＴのパターン領域３５が形成され、パターン領域３５にウエハに転写すべき回路パターンが形成されている。また、パターン領域３５のＹ方向の外側には幅がＭ以上の遮光部よりなる禁止帯３６が形成されている。本例では、パターン領域３５をスリット状の照明領域２０でＸ方向に２回走査

して、パターン領域３５のパターンをウエハ上に転写する。そして、例えば１回目の走査でほぼ右半分の領域３５ａのパターンをウエハ上に転写し、２回目の走査でほぼ左半分の領域３５ｂのパターンをウエハ上に転写する。

【００２９】

この際に、領域３５ａの左端部と領域３５ｂの右端部とはＹ方向に幅Ｍの接続部３５ｃで重なるようにして、この接続部３５ｃを照明領域２０の照度が次第に低下する領域２０ａ又は２０ｂが走査するようにする。これにより、接続部３５ｃの照度分布が均一になると共に、転写されるパターンの位置ずれが防止される。また、パターン領域３５内の照度を一定にするため、パターン領域３５のＹ方向の端部において、照明領域２０の照度が次第に低下する領域２０ａ及び２０ｂにより走査される領域が生じないようにする。照明領域２０の内で照度が一定の領域のＹ方向の幅はＬ、照度が次第に０になる領域２０ａ及び２０ｂのＹ方向の幅はそれぞれＭであるため、パターン領域２０のＹ方向の幅ＬＴは次のようになる。

【数３】

$$LT = 2 \cdot L + M$$

【００３０】

一般に、パターン領域３５を照明領域２０でＸ方向にｎ回走査することにより、パターン領域３５のパターンをウエハ上に転写するものとして、照度が次第に低下する領域２０ａ又は２０ｂのみにより照明される領域が生じないようにするには、パターン領域３５のＹ方向の幅ＬＴは次のように定めればよい。

【数４】

$$LT = n \cdot T + (n - 1) \cdot M$$

【００３１】

図４（ａ）は、図１のウエハ２８上の矩形のスリット状の露光領域２０Ｐを示し、露光領域２０Ｐは図２（ａ）のレチクル１９上の照明領域２０と共役である。この場合、投影光学系２７の投影倍率がβであるため、露光領域２０ＰのＸ方向の幅はβ・Ｄで、Ｙ方向の幅はβ・（Ｌ＋２Ｍ）である。また、図４（ｂ）に示すように、露光領域２０Ｐの内の両側のＹ方向の幅がβ・Ｍの領域２０ａＰ及

び２０ｂＰではそれぞれ照度Ｓがほぼ直線的に０に低下している。また、スリットスキャン露光を行う際には、露光領域２０Ｐに対してウエハ２８はＸ方向に走査されるため、露光領域２０Ｐの相対走査の方向に垂直なＹ方向の照度分布も台形状である。

【００３２】

次に、露光領域２０Ｐの相対走査の方向であるＸ方向の幅β・Ｄの条件について説明する。この場合、図１のパルスレーザー光源１２のパルス発光の周期（即ち、発光周波数ｆの逆数）をＴとして、スリットスキャン露光を行っている際に１周期Ｔの間にウェハ２８がＸ方向に走査される距離をΔＬとすると、露光領域２０ＰのＸ方向の幅β・Ｄを、距離ΔＬの整数倍に設定する。また、ウエハ２８のＸ方向の走査速度をβ・Ｖとすると、距離ΔＬはＴ・β・Ｖである。即ち、ｍを１以上の整数として次式が成立する。

【数５】

$$\beta \cdot D = m \cdot \Delta L = m \cdot T \cdot \beta \cdot V$$

【００３３】

図４（ａ）では、β・Ｄ＝４・ΔＬの場合を示している。このときには、例えばパルス発光があった時点で露光領域２０Ｐのエッジ部に存在する露光点Ｑ０は、露光領域２０Ｐの内部で３パルスのパルスレーザー光に照射され、露光領域２０Ｐのエッジ部で２パルスのパルスレーザー光に照射される。また、１回のパルス発光で露光領域２０Ｐの内部の露光点に照射されるエネルギーをΔＥとすると、露光点Ｑ０には、４・ΔＥ（＝ΔＥ／２＋３・ΔＥ＋ΔＥ／２）のエネルギーが照射される。また、例えばパルス発光があった時点で露光領域２０Ｐのエッジ部の内側に存在するウエハ上の露光点Ｑ１にも、４・ΔＥのエネルギーが照射され、パルス発光があった時点で露光領域２０Ｐのエッジ部の外側に存在するウエハ上の露光点Ｑ２にも、４・ΔＥのエネルギーが照射される。このように、本例によれば、ウエハ上の露光領域２０Ｐによって走査される全ての露光点に対して、同一のｍパルスのパルスレーザー光が照射される。従って、露光領域２０Ｐ中の照度分布が一定の領域で走査される露光点では照度分布は一定となる。

【００３４】

なお、露光領域２０Ｐの両側の領域２０ａＰ及び２０ｂＰにより１回走査される露光点では、照射されるパルス数はｍパルスでも照射されるエネルギーは少なくなっている。しかしながら、後述のように、本例ではスティッチングの際の接続部を領域２０ａＰ及び２０ｂＰで２回走査するようにしているので、接続部の各露光点でも照射されるエネルギーはｍ・ΔＥとなり、ウエハ上の全ての露光点において照射されるエネルギーの量は同一となり、照度むらが無くなっている。

【００３５】

次に、本例のスティッチング及びスリットスキャン露光の動作の一例につき説明する。先ず、図１において、レチクル１９上のスリット状の照明領域２０をパルスレーザー光ＩＬで照明した状態で、駆動装置２６及びレチクルステージ２１を介してレチクル１９を　Ｘ方向に一定の速度Ｖで走査する。そして、それに同期して、駆動装置３３及びウエハステージ３０を介してウエハ２８をＸ方向に一定の速度β・Ｖで走査する。このように、レチクル１９及びウエハ２８を走査する際には、例えばレチクル１９上の所定のアライメントマークとウエハ２８上の所定のアライメントマークとが合致したときの、レーザー干渉計２４の計測値とレーザー干渉計３２の計測値に投影倍率βを乗じた値との差を基準値として記憶しておき、レーザー干渉計２４の計測値とレーザー干渉計３２の計測値に投影倍率βを乗じた値との差がその予め記憶した基準値となるように駆動装置２６及び３３の動作を制御する。従って、レチクル１９及びウエハ２８は常に所定の関係で互いに静止した状態で、それぞれ照明領域２０及び露光領域２０Ｐに対して幅の狭い方向に走査される。

【００３６】

これにより、図３に示すように、レチクル１９側ではスリット状の照明領域２０が軌跡３７に沿ってパターン領域３５の右側の領域３５ａを相対的に走査する。また、図５（ａ）に示すように、ウエハ２８側ではスリット状の露光領域２０Ｐが軌跡３７Ｐに沿ってパターン領域３５に対応する被露光領域４０の左側の領域４０ａを相対的に走査する。

【００３７】

次に、１回目のスリットスキャン露光が終了した時点で、図３においてスティ

ッチングにより、レチクル１９をＹ方向に移動することにより、照明領域２０を軌跡３８に沿ってパターン領域３５の左上に移す。また、図５（ａ）において、ウエハ２８を－Ｙ方向に移動することにより、スリット状の露光領域２０Ｐを軌跡３８Ｐに沿って被露光領域４０の右下に移す。その後、レチクル１９をＸ方向に速度Ｖで走査すると共に、ウエハ２８を－Ｘ方向に速度β・Ｖで走査することにより２回目のスリットスキャン露光を行う。この結果、図３に示すように、レチクル１９側ではスリット状の照明領域２０が軌跡３９に沿ってパターン領域３５の左側の領域３５ｂを相対的に走査する。また、図５（ａ）に示すように、ウエハ２８側ではスリット状の露光領域２０Ｐが軌跡３９Ｐに沿ってパターン領域３５に対応する被露光領域４０の右側の領域４０ｂを相対的に走査する。

【００３８】

また、図３に示すように、１回目の走査と２回目の走査とにおいて、レチクル１９のパターン領域３５のＹ方向の中央部の接続部３５ｃでは、照明領域２０の照度が低下する左側の領域２０ａと照度が低下する右側の領域２０ｂとにより重ねて露光が行われるようにする。これにより、図５（ａ）に示すように、ウエハ２８の被露光領域４０のＹ方向の中央部の接続部４０ｃでは、スリット状の露光領域２０Ｐの照度が低下する右側の領域２０ａＰと照度が低下する左側の領域２０ｂＰとにより重ねて露光が行われる。例えば、接続部４０ｃ内の露光点Ｑ３においては、１回目の露光の際の照度は図５（ｂ）の照度ＳＡとなり、２回目の露光の際の照度は照度ＳＢとなる。領域２０ａＰと領域ｂＰとのＹ方向の照度分布は互いに対称に直線的に０に低下しているので、照度ＳＡと照度ＳＢとの和の照度は、露光領域２０Ｐの照度が一定の領域の照度ＳＣと等しくなる。

【００３９】

また、既に説明したように、露光領域２０Ｐにより１回走査される露光点では、全てｍパルスのパルスレーザー光が照射される。従って、接続部４０ｃ内の露光点Ｑ３では、露光領域２０Ｐの２回の走査により非接続部の露光点と等しい量のエネルギーが照射され、照度分布がウエハ２８上の全露光点で均一化されている。更に、接続部４０ｃ内の露光点では２回の走査により照射されるパルス数は、非接続部の露光点の２倍の２ｍ個となっている。従って、接続部４０ｃでは特

にパルスレーザー光のパルス毎のエネルギーのばらつきやスペックルの影響が低減されている。具体的に、パルスレーザー光のパルス毎のエネルギーのばらつきに起因する照度のばらつきは、接続部４０ｃでのばらつきが非接続部でのばらつきの$1/2^{1/2}$に抑えられている。

【００４０】

次に、本実施例では、図５（ａ）のウエハ２８上の領域４０ａをスリットスキャン露光する際に、レチクル１９とウエハ２８との相対位置をレーザー干渉計２４及び３２でモニタし、レチクル１９とウエハ２８との相対的な位置ずれ量を機械的な制御誤差として、図１の記憶装置２５ａに記憶する。即ち、１回目の走査により、ウエハ２８上の任意の露光点の像がｍパルス分のパルスレーザー光の照射で形成されるならば、各パルス発光に同期してＸ方向の相対位置ずれ量をモニタする。各パルス毎のＸ方向の相対位置ずれ量をΔx_iとして、Σを添字ｉに関する１〜ｍまでの和を表すとすると、次の演算により平均的な位置ずれ量〈Δｘ〉を計算できる。

【数６】

$$\langle \Delta x \rangle = \Sigma \Delta x_i / m$$

【００４１】

同様に、相対走査の方向であるＸ方向に垂直なＹ方向のレチクル１９とウエハ２８との相対的な位置ずれ量Δy_i、及びレチクル１９とウエハ２８との回転誤差をも記憶装置２５ａに記憶しておく。従って、１個の位置ずれ量Δx_iの記憶容量をΔＭとすると、記憶装置２５ａの記憶容量としては、ΔＭ×ｍ個分の数倍の容量があればよいが、例えば近傍の位置での相対位置ずれ量等を平均化することによって、記憶する相対位置ずれ量等の個数を少なくすることもできる。このように記憶装置２５ａに記憶された相対位置誤差及び回転誤差は、ウエハ２８上の接続部４０ｃにおける所謂「ショット内歪」の原因となる。

【００４２】

次に、２回目の走査により図５（ａ）の領域４０ｂへの露光を行う際に、主制御系２５は記憶装置２５ａから読み出した相対位置誤差及び回転誤差に合わせるように、駆動装置２６及び３３を介してレチクルステージ２１及びウエハステージ３０の動作を制御する。これにより、ウエハ２８上の接続部４０ｃでのパターンの重ね合わせ精度が高精度になる。また、通常レチクルステージ２１及びウエハステージ３０のＸ方向及びＹ方向の位置決め精度をΔｘ，Δｙとすると、接続部４０ｃでの重ね合わせ誤差はそれぞれ$2^{1/2}$Δｘ及び$2^{1/2}$Δｙとなる。これに対して、本例の方法では最初の領域４０ａの露光の際のショット歪に合わせて次の領域４０ｂの露光の際の位置関係を補正する（同じショット歪になる様にレチクル１９及びウエハ２８の位置を制御する）ので、重ね合わせ誤差はΔｘ，Δｙだけである。

【００４３】

次に、ウエハ２８の全部の露光面への露光方法につき説明する。先ず図５（ａ）の方法を適用した場合には、図６に示すように、それぞれスリットスキャン露光により順次隣接する領域４０－１ａ，４０－１ｂ，４０－２ａ，４０－２ｂ，・・・・，４０－４ｂ，４０－４ａへの露光が行われる。但し、図６の方法は図５（ａ）の方向と走査方向は逆である。また、２個の走査領域、例えば領域４０－１ｂ及び４０－１ａに対してそれぞれレチクル１９のパターン領域３５の回路パターンが転写される。この方法では、レチクル１９のパターン領域３５のウエハ２８上での共役像内での走査方向が反対になる。また、この走査方法によれば、そのパターン領域３５のパターンをウエハ２８上に短時間で転写でき、ウエハ２８の膨張等の影響を受け難い利点がある。その反面、走査方向の特性による接続部の精度が悪化する虞があり、図３の照明領域２０のＹ方向への軌跡３８に対応するレチクル１９の移動を高速で行う必要がある。

【００４４】

次に、図７に示すように、最初にレチクル１９のパターン領域３５の例えば右半分の領域３５ａだけをウエハ２８上の対応する領域に連続して露光して、次にパターン領域３５の左半分の領域３５ｂだけをウエハ２８上の対応する領域に連続して露光する方法もある。即ち、この方法では、先ず図７（ａ）に示すように

、ウエハ２８上の領域４０－１ｂ，４０－２ｂ，・・・，４０－４ｂへの露光が行われ、次に図７（ｂ）に示すように、図７（ａ）の軌跡と平行にウエハ２８上の領域４０－１ａ，４０－２ａ，・・・，４０－４ａへの露光が行われる。この方法によれば、レチクル１９のパターン領域３５に対応するウエハ２８上の２個の被露光領域（例えば領域４０－１ｂ及び４０－１ａ）ではスリット状の露光領域２０Ｐの走査方向が同じになる。これにより接続部４０ｃでの重ね合わせ精度が向上する場合がある。

【００４５】

次に、上述実施例では投影光学系２７として屈折光学系が使用されているので、図２（ａ）に示すように、レチクル１９上の照明領域は矩形の照明領域２０となっている。これに対して、特に露光光の短波長化に対しては、凹面鏡等を用いた反射屈折光学系により構成される投影光学系を用いると収差等の点で有利である。また、凹面鏡等は光軸から離れた領域の方が収差が少ないため、反射屈折光学系を用いた場合には、レチクル１９上のスリット状の照明領域は、図８（ａ）に示すように、円弧状の照明領域４１となる。この場合でも、照明領域４１の相対走査の方向の幅Ｄは一定であり、照明領域４１の相対走査の方向に垂直な長手方向をＹ方向とすると、照明領域４１のＹ方向の照度分布は、図８（ｂ）に示すように台形状になっている。即ち、照明領域４１のＹ方向の両端の領域４１ａ及び４１ｂでは、照度分布は直線的に０に落ちている。このような照度分布に設定することにより、図１の実施例と同様にスティッチングの際の接続部の照度むらを小さくすることができる。

【００４６】

次に、本発明の他の実施例につき図９を参照して説明する。本実施例は、図１１を参照して説明したように正６角形状の露光領域３でウエハ上を走査する場合に本発明を適用したものである。

図９（ａ）及び（ｂ）は本実施例でスティッチングを行う場合のウエハ上の接続部４を示し、この図９（ａ）及び（ｂ）において、正６角形状の露光領域３での照度分布は均一であるが、露光光としてはパルスレーザー光が使用されている。また、相対走査の方向をＸ方向及び－Ｘ方向とすると、露光領域３の間隔がＷ

の対向する２辺がスティッチングの方向であるＹ方向に平行になっている。この場合でも、スリットスキャン露光の際に、パルス発光の１周期の間にウエハがＸ方向又は　Ｘ方向に移動する距離をΔＬとすると、その間隔Ｗは、１以上の整数ｍを用いて次のように設定される。

【数７】

$$W = m \cdot \Delta L$$

【００４７】

図９（ａ）及び（ｂ）ではｍ＝８の場合が示されており、１回の走査により、ウエハ上の非接続部の露光点Ｐ０には常に８パルス分のエネルギーが照射される。

また、本実施例では、ウエハを露光領域３に対してＸ方向に走査する場合と、ウエハを露光領域３に対して－Ｘ方向に走査する場合とで、パルスレーザ光源がパルス発光するときのウエハのＸ方向の位置が同一になるようにする。例えば図９（ａ）において、ウエハ上の接続部４内の露光点Ｐ９が露光領域３に対してＸ方向に走査されるとき、即ち露光点Ｐ９が露光領域３の右側の２等辺３角形の領域３ａを走査するときに、パルス発光が行われるときの露光点Ｐ９のＸ方向の位置を位置８とする。そして、２回目の走査によりその露光点Ｐ９が露光領域３に対して－Ｘ方向に走査されるとき、即ち露光点Ｐ９が露光領域３の左側の２等辺３角形の領域３ｂを走査するときに、パルス発光が行われるときの露光点Ｐ９のＸ方向の位置を位置４２とすると、位置４２と位置８とが合致することを意味する。図９（ａ）の場合には、領域３ａ内に位置８が５箇所あり、領域３ｂ内に位置４２が３箇所あるので、露光点Ｐ９には２回のスリットスキャンス露光により合計で８パルス分のエネルギーが照射される。

【００４８】

また、図９（ｂ）は図９（ａ）の場合と比べて、パルス発光のタイミングがＸ方向にΔＬ／２だけずれている場合を示す。図９（ｂ）においては、露光点Ｐ９が露光領域３の右側の２等辺３角形の領域３ａを走査するときに、パルス発光が行われるときの露光点Ｐ９のＸ方向の位置１０に対して、２回目の走査により露光点Ｐ９が露光領域３の左側の２等辺３角形の領域３ｂを走査するときに、パル

ス発光が行われるときの露光点P9のX方向の位置43が等しくなるようにする。図9（b）の場合には、領域3a内に位置10が4箇所あり、領域3b内に位置43が4箇所あるので、露光点P9には2回のスリットスキャン露光により合計で8パルス分のエネルギーが照射される。一般に、本例によれば、接続部4内の各露光点において、非接続部の露光点P0と同様に8パルス分のエネルギーが照射され、照度むらは生じない。なお、以上の実施例では、1枚のレチクルを用いたスティッチング動作について説明したが、複数枚のレチクルを同一のレチクルステージに載置し、スティッチング時にレチクルを交換しながら走査露光を繰り返し行うようにしても良い。

【0049】

なお、本発明は上述実施例に限定されず本発明の要旨を逸脱しない範囲で種々の構成を取り得ることは勿論である。

【0050】

【発明の効果】

本発明の第1の投影光学装置によれば、パルス発光型の光源を用いてスティッチング及びスリットスキャン露光方式で露光を行う場合に、感光基板上の接続部の各点が2回のスリットスキャン露光により非接続部と同じ照度で露光されるので、感光基板上の接続部の照度むらを低減できる利点がある。

【0051】

また、露光光による照明領域の所定の方向に相対的にマスク及び感光基板を同期して走査する際の、マスクと感光基板との相対的な位置の誤差を記憶する記憶手段を設けた場合には、接続部での1回目の走査における相対的な位置の誤差を記憶して、接続部での2回目の走査の際にその相対的な誤差に合わせて位置制御を行うことにより、接続部での重ね合わせ誤差を小さくできる。

また、マスク上の露光光による照度分布が台形状の照明領域の第2の方向の、照度分布が一定の領域の長さをL、その照度分布が台形状の領域の両側の照度が次第に小さくなる領域の長さをそれぞれMとして、マスク上に形成される転写用のパターンの露光光による照明領域のその第2の方向の幅LTを、{n・L＋(n－1)・M}に設定することにより、マスク上の転写用のパターンが常に均一

な照度で照明される。

【0052】

そして、露光光による照明領域のその第2の方向に相対的にマスクを移動させるマスク移動手段を設けた場合には、マスク側でもスティッチングを行うことができる。

次に、本発明の第2の照明光学装置によれば、接続部において1回目の走査時のパルス発光の位置と2回目の走査時のパルス発光の位置とが等しくなるので、接続部の各露光点での照度は非接続部の各露光点での照度と等しくなり、照度むらが低減される。

【図面の簡単な説明】

【図1】

本発明による投影光学装置の一実施例を示す構成図である。

【図2】

（a）は図1のレチクル19上のスリット状の照明領域を示す平面図、（b）はその照明領域の照度分布を示す分布図である。

【図3】

その実施例のレチクルのパターンを示す平面図である。

【図4】

（a）はその実施例のウエハ上のスリット状の露光領域を示す平面図、（b）はその露光領域の照度分布を分布図である。

【図5】

（a）はウエハ上の被露光領域を示す平面図、（b）はその被露光領域における照度分布を示す分布図である。

【図6】

その実施例でのウエハ上のスリットスキャン露光の軌跡の一例を示す平面図である。

【図7】

その実施例でのウエハ上のスリットスキャン露光の軌跡の他の例を示す平面図である。

【図８】

（ａ）はレチクル上の照明領域の変形例を示す平面図、（ｂ）はその照明領域の変形例の照度分布を示す分布図である。

【図９】

（ａ）は本発明の他の実施例におけるパルス発光の位置の関係の一例を示す拡大平面図、（ｂ）は本発明の他の実施例におけるパルス発光の位置の関係の他の例を示す拡大平面図である。

【図１０】

（ａ）は従来の連続発光型の光源を備えた投影露光装置でスティッチング及びスリットスキャン露光を行う際のレチクル上の照明領域の相対走査の様子を示す平面図、（ｂ）は図１０（ａ）に対応するウエハ上の露光領域の相対走査の様子を示す平面図である。

【図１１】

正６角形の露光領域でスティッチング及びスリットスキャン露光を行う場合に、パルス発光型の光源を使用するときの感光基板上の照度むらの説明に供する線図である。

【符号の説明】

１２　パルスレーザー光源

１３　照明最適化光学系

１５　視野絞り

１６　リレーレンズ

１８　コンデンサーレンズ

１９　レチクル

２０　レチクル上の矩形のスリット状の照明領域

２０Ｐ　ウエハ上の矩形のスリット状の露光領域

２１　レチクルステージ

２３　ガイド

２４，３２　レーザー干渉計

２５　主制御系

26, 33 駆動装置

28 ウエハ

30 ウエハステ ジ

34 レーザー光源制御装置

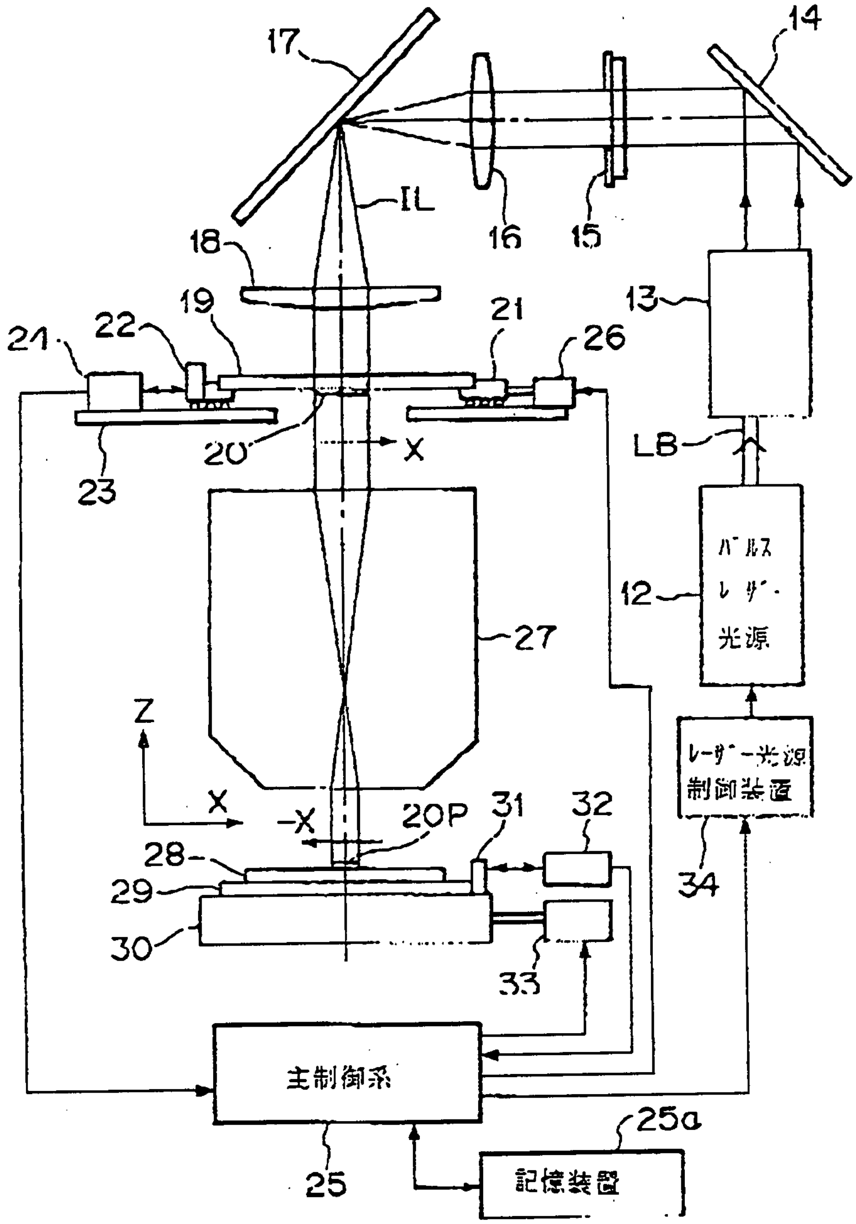
35 パターン領域

40 被露光領域

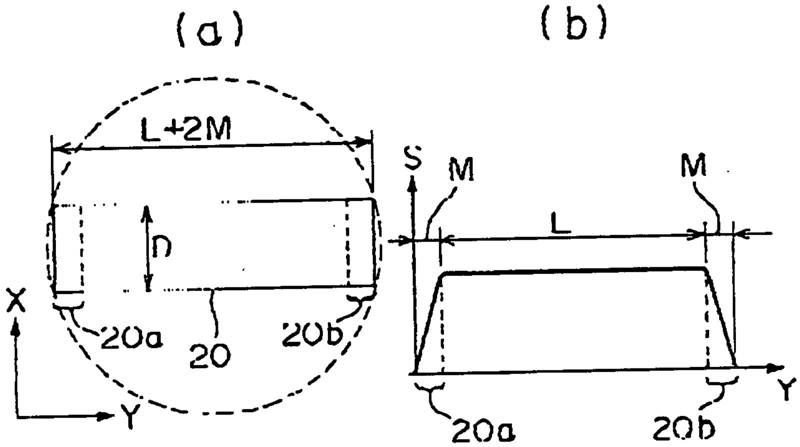
整理番号－９２[illegible]０９５４ （１）

【書類名】 図面

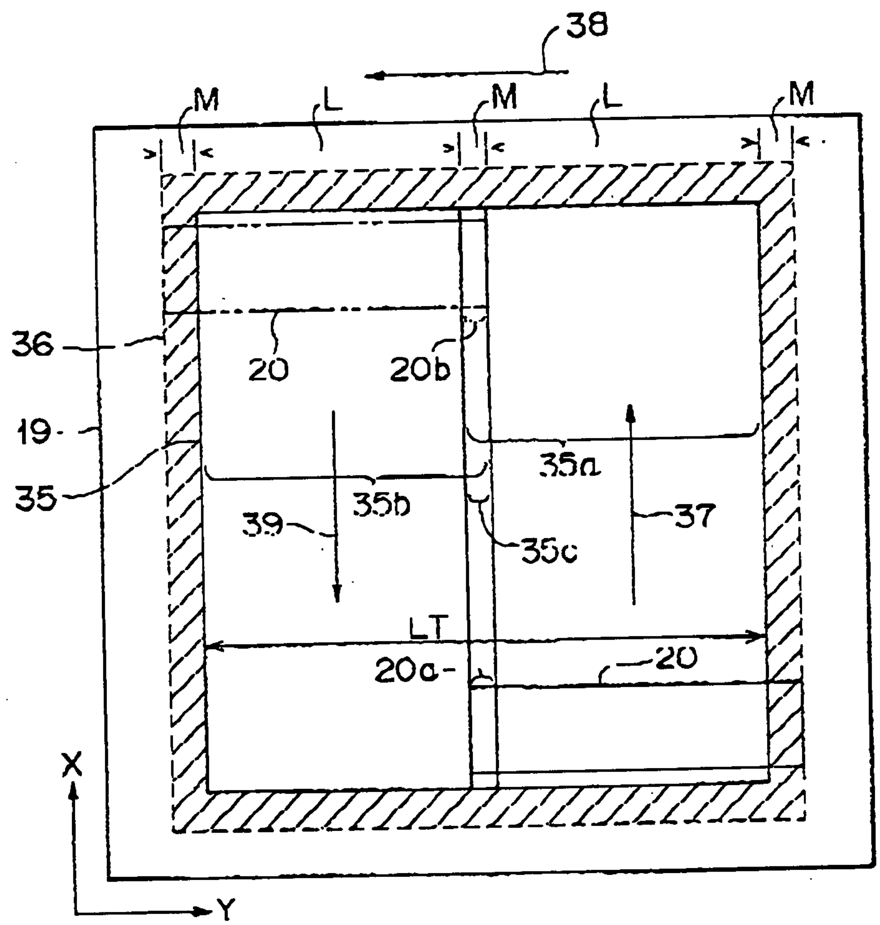
【図１】



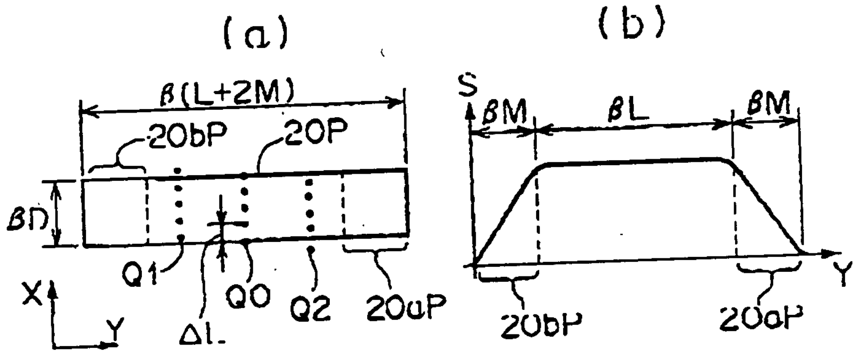
【図2】


(a)
(b)
L+2M
D
X
Y
20a
20
20b
S
M
M
L
Y
20a
20b

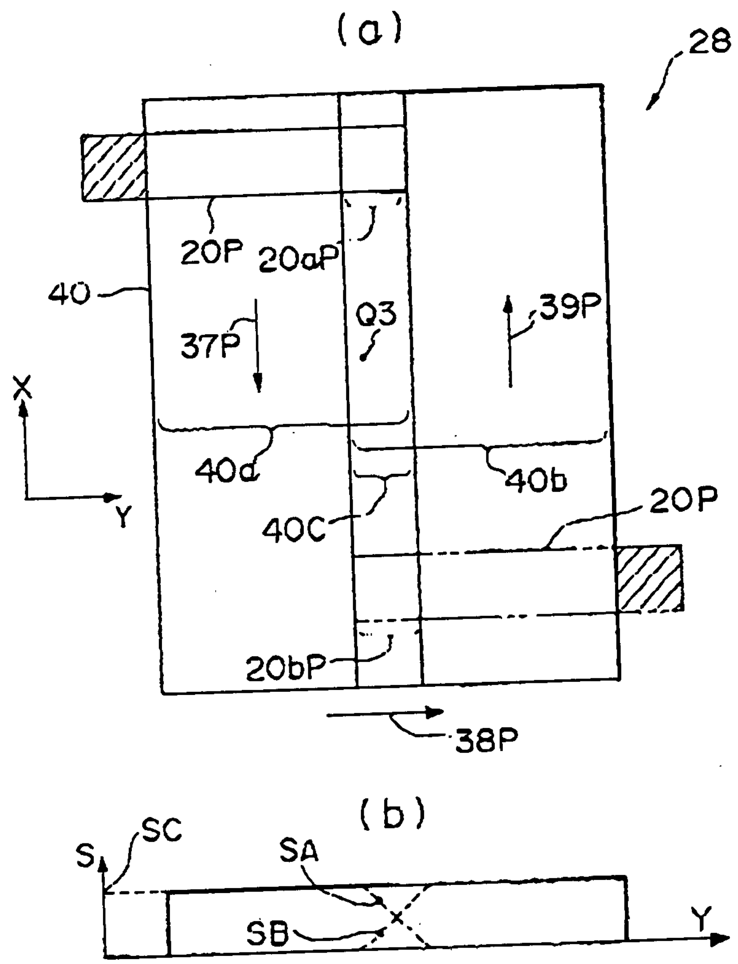
【図3】


38
M
L
M
L
M
36
20
20b
19
35
35a
35b
39
35c
37
LT
20a
20
X
Y

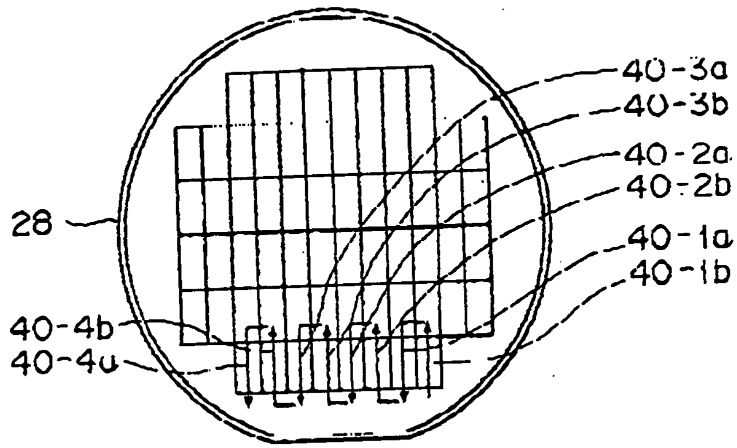
【図4】


(a)
(b)
β(L+2M)
20bP
20P
βD
Q1
Q0
Q2
20aP
ΔL
X
Y
S
βM
βL
βM
Y
20bP
20aP

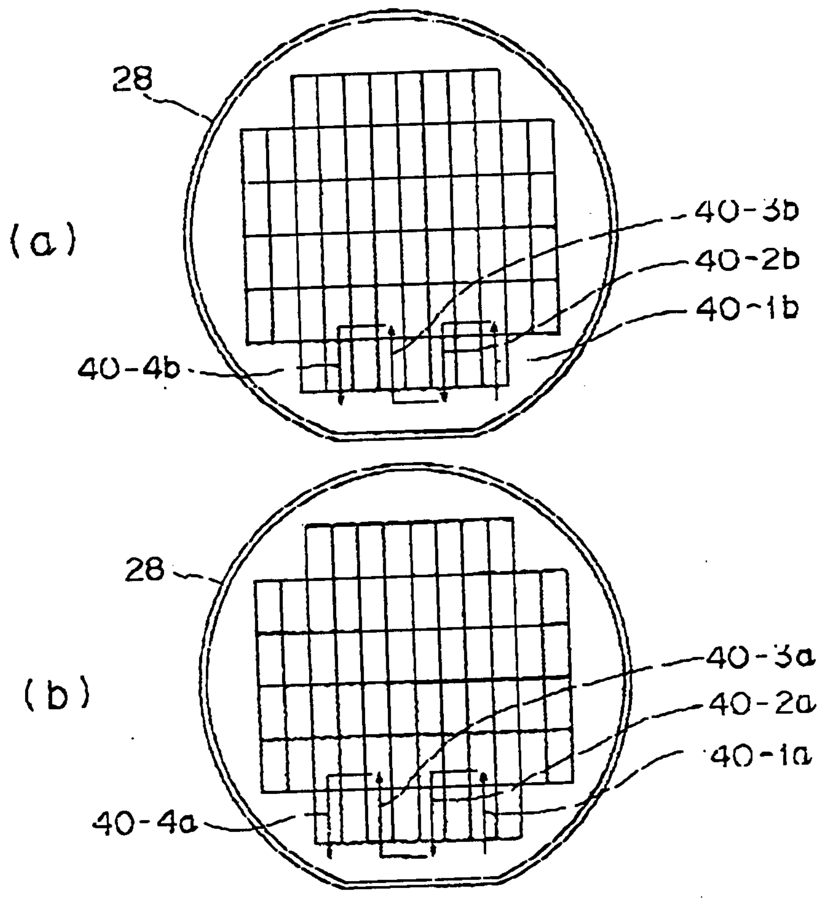
【図5】


(a)
28
20P
20aP
40
37P
Q3
39P
X
Y
40a
40b
40C
20P
20bP
38P
(b)
S
SC
SA
SB
Y

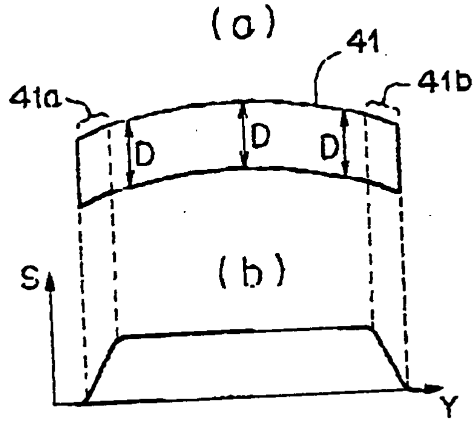
【図6】


40-3a
40-3b
40-2a
40-2b
40-1a
40-1b
28
40-4b
40-4a

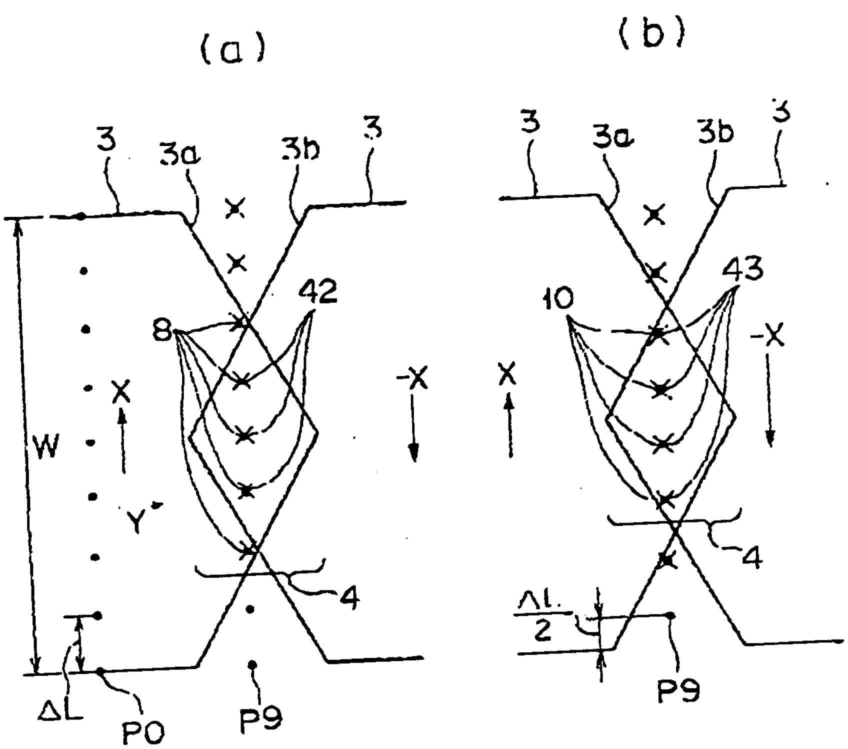
【図7】


28
(a)
40-3b
40-2b
40-1b
40-4b
28
(b)
40-3a
40-2a
40-1a
40-4a

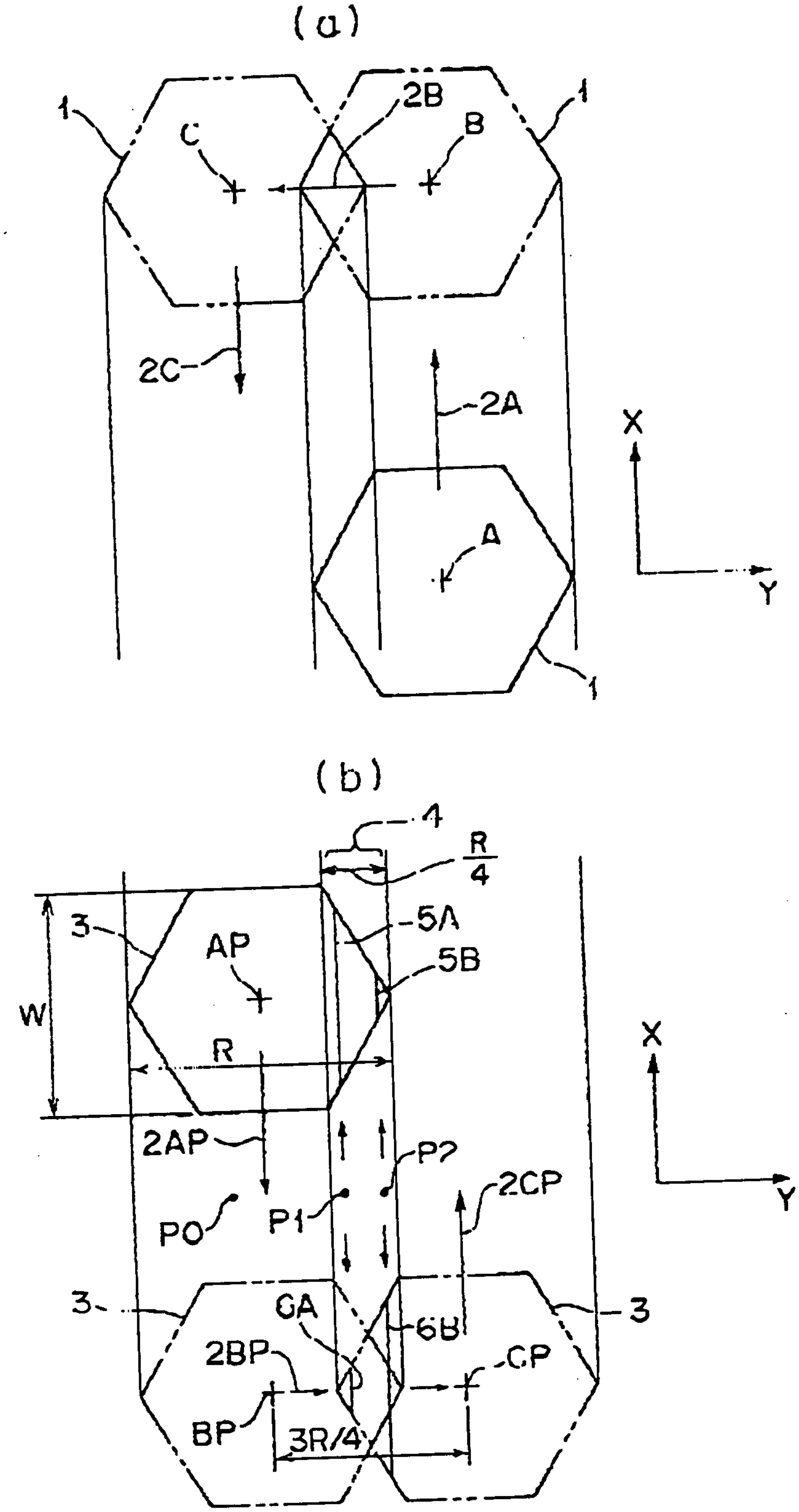
【図8】



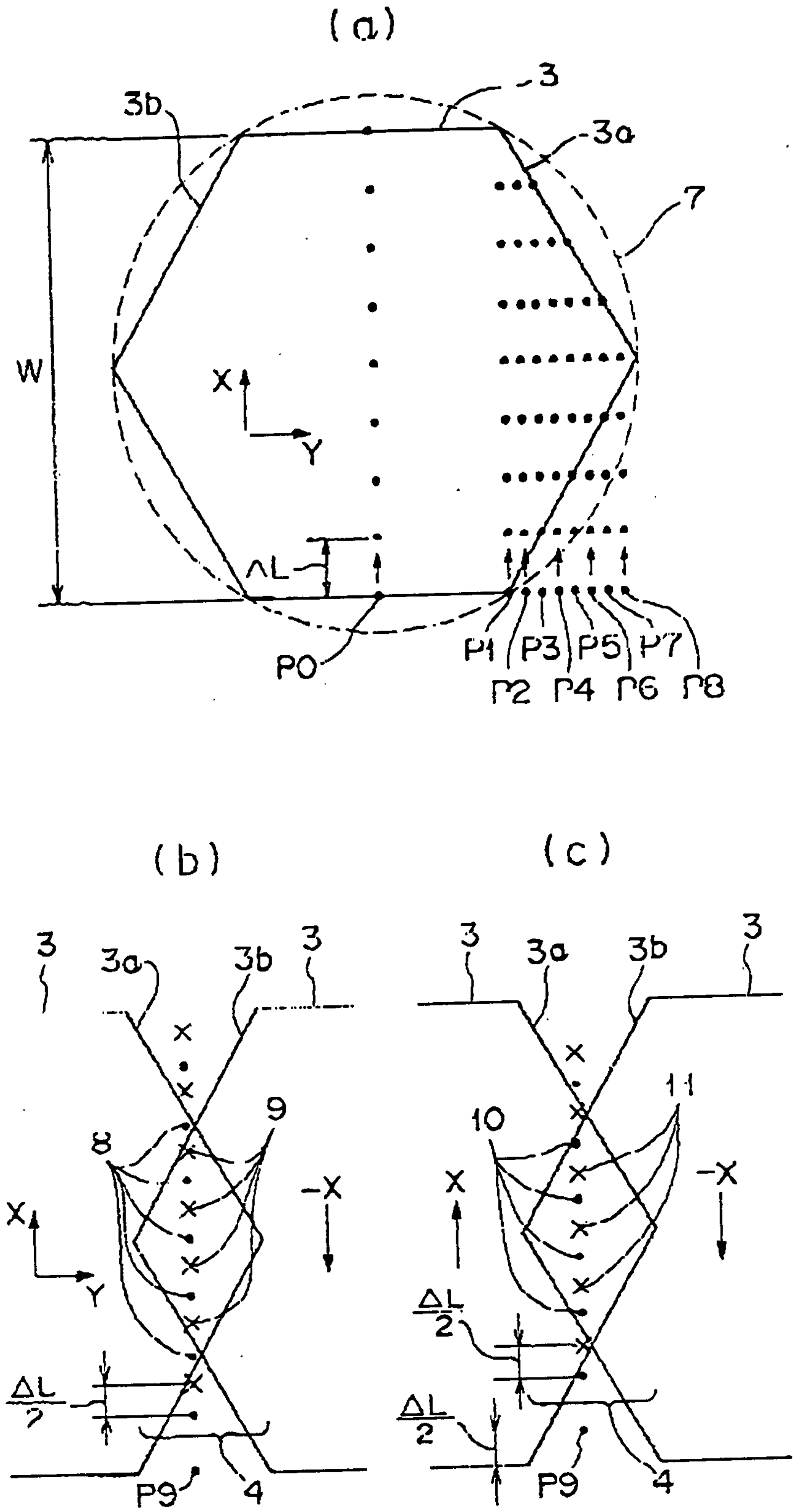
【図9】



【図１０】


(a)
1
C
2B
B
1
2C
2A
X
Y
A
1
(b)
4
R/4
3
AP
5A
5B
W
R
X
2AP
P2
P0
P1
2CP
Y
3
6A
6B
3
2BP
CP
BP
3R/4

【図11】


(a)
3
3b
3a
7
W
X
Y
ΔL
P0
P1
P3
P5
P7
P2
P4
P6
P8
(b)
(c)
3
3a
3b
3
8
9
-X
X
Y
ΔL/2
P9
4
3
3a
3b
3
10
11
X
-X
ΔL/2
ΔL/2
P9
4

整理番号＝９２[redacted]０９５４　[redacted]　（１）

【書類名】　要約書　Abstract

【要約】

【目的】　パルス発光型の光源を用いてスティッチング及びスリットスキャン露光方式で露光を行う場合に、感光基板上で２回走査されて露光される接続部の照度むらを低減する。

【構成】　ウエハ上の露光領域を矩形のスリット状の露光領域２０Ｐとして、露光領域２０Ｐに対してＸ方向又は－Ｘ方向にウエハを走査して露光を行う。露光領域２０ＰのＹ方向の照度分布Ｓを台形状にして、ウエハ上の接続部では、露光領域２０Ｐの右側の照度が次第に低下する領域２０ａＰと左側の照度が次第に低下する領域２０ｂＰとで露光が行われるようにする。

【選択図】　図１